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*YOUNG, CHAS. A., ... 536 North Fourth Street, Philadelphia.

Members, 537; Associates, 144; Foreign Members, 51.

Deceased.

Blossom, T. M.,	1876
Brown, A. J.,	1875
Clemes, J. P.,	1876
Daddow, S. H.,	1875
D'Aligny, H. F. Q.,	1875
Firmstone, William,	1877
Harris, Stephen,	1874
Hunt, Thomas,	1872
Jenney, F. B.,	1876
Lee, Col. Washington,	1872
Liebenau, Charles von,	1875
Lord, John C.,	1872
Moore, Charles W.,	1877
Newton, Henry,	1877
Painter, Howard,	1876
Richter, C. E.,	1877
Schirmer, J. F. L.,	1877
Steitz, Augustus,	1876
Stoelting, Hermann,	1875
Walz, Isidor,	1877
Witherbee, J. G.,	1875

RULES.

(ADOPTED MAY, 1873. AMENDED MAY, 1875, AND MAY, 1877.

I.

OBJECTS.

The objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful minerals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versâ*, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; *Provided*, that honorary members, and members and associates permanently residing in foreign countries, shall not be entitled to vote or to be members of the Council.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars, payable upon election, and ten dollars per annum, payable in advance at the annual meeting; *Provided*, that persons elected at the February meeting shall not be liable to dues at the first annual meeting following; and members and associates permanently residing in foreign countries, excepting Canada, shall be liable to such annual or other payments only as the Council may impose, to cover the cost of supplying them with publications. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may at the discretion of the Council be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; *Provided*, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may by vote of a majority of all its members declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the

Council meetings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *Provided*, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members, or foreign members or associates), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary, or presenting it in person at the annual meeting: *Provided*, that no member or associate, in arrears since the last annual meeting, shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices, shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

General meetings of the Institute shall take place on the fourth Tuesday of February, May, and October; and the May meeting shall be considered the annual meeting, at which a report of the proceedings of the Institute, and an abstract of the accounts, shall be furnished by the Council. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained. All notices may be given by circular, mailed to members and associates, or through the Bulletin, published in the regular organ of the Institute, at the discretion of the Council.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of the majority of the members then present. The place of meeting shall be fixed in advance by the Institute, or, in default of such determination, by the Council, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS.

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given at each General Meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion, advanced in papers or discussions, at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

VIII.

AMENDMENTS.

These Rules may be amended, at any annual meeting, by a two-thirds vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

PROCEEDINGS OF MEETINGS.

MAY, 1876, TO FEBRUARY, 1877.

ANNUAL MEETING, EASTON, PA.

May, 1876.

The annual meeting of the Institute was held at the office of the Secretary on Tuesday, May 23d. President Holley appointed Messrs. J. C. Kent and Frank Firmstone scrutineers to examine the ballots of the Institute.

The following were declared elected:

President—Abram S. Hewitt.

Vice-Presidents—W. P. Blake, E. B. Coxe, R. W. Raymond.

Managers—R. W. Hunt, J. S. Newberry, T. F. Witherbee.

Treasurer—T. D. Rand.

Secretary—T. M. Drown.

The meeting was then adjourned to June 20th. The adjourned meeting to be held in Philadelphia.

ADJOURNED MEETING, PHILADELPHIA,

June, 1876.

THE opening session* was held in the hall of the Franklin Institute, on Tuesday evening, June 20th, President Holley in the chair. The President introduced Mr. Franklin B. Gowen, who addressed the Institute as follows:

MR. PRESIDENT AND GENTLEMEN: It has been made my pleasant duty to welcome you to the city of Philadelphia, but in so doing I shrink, with some natural reluctance, from appearing before an audience so much better fitted than I am to cope with the subjects which are usually presented to your association, and I can assure you that no trembling neophyte, first venturing within the groves of the Academy, or walking, with sacred reverence, in the gardens of Plato, felt more natural dread at the consequence of his own temerity than I do in appearing before an audience composed of gentlemen belonging to a scientific society of which I am but too sensible that until now I have been a member only in name.

In olden times, upon entering a temple sacred to the worship of any deity, it was customary to lay some offering upon the altar, and, in following this custom, it will be my duty, before entering upon the more pleasant part of the task which is assigned me, to call your attention to a subject with which I have been somewhat familiar, and which is entirely within the scope of your investigations, in the belief that I may throw out some hints or some suggestions of a process that may be fully developed by some of you, and eventually lead to the introduction of that which may be of service to the human race.

The satirist who described the philosopher whom he met, as engaged in the process of extracting sunbeams from cucumbers,

* A joint discussion of the subject of Technical Education, by the members of the American Society of Civil Engineers and the American Institute of Mining Engineers, was held in the hall of the Franklin Institute, on Monday evening, June 19th, and Tuesday morning, June 20th. This discussion has been printed in a separate pamphlet by both societies.

probably uttered a truth, when he was dealing only in what he supposed to be the perfection of satire, for it is now known to all that the vegetable growth of the primeval world stored up in the shape of carbon the sunbeams which shone upon the dawn of creation, the product of which, now deposited in the recesses of the earth, is that mass of fuel, without which the civilization of the world would cease to move with its advancing strides.

In connection with the development of this fuel, I desire to direct your minds more particularly to anthracite coal, and to ask the attention of the gentlemen who are charged with determining the proper economical methods of extracting the wealth which Nature has stored up for us, to the great waste which has heretofore characterized the mining of anthracite coal in Pennsylvania, and to a process which has recently been discovered for the utilization of that waste. Most of you know, that in the preparation of anthracite coal for the wants of the market, it is broken into different sizes, by which a vast amount of culm is produced, which heretofore has been considered entirely useless, so that there is now left in the districts in which I am particularly interested, almost 40,000,000 tons of this waste material lying in huge mountains, some of which, if they remain to future ages, would probably puzzle the geologist to account for. This vast amount of fuel, containing in itself as much carbon as the most merchantable coal, has heretofore been considered useless. Several attempts have been made to introduce the French and Belgium methods of converting it into artificial fuel, by admixture with binding substances, and compression by mechanical means, but the cost of these processes has been at least one dollar per ton, and heretofore, except for domestic purposes, and at shipping ports, where there is an accumulation of this dust near to market, they have been practically useless for any commercial purpose. The attention of the company which I represent, and of its general superintendent, Mr. John E. Wootten, was called to this matter some months ago, and Mr. Wootten has invented a plan whereby this waste fuel, heretofore thrown away as useless, can be used in making steam, both in stationary and locomotive engines, without any admixture with other substances, and without any compression into blocks.

The coal dust or culm, in its natural state, is thrown into the furnace, and a result obtained which is nearly, if not quite, equal to that which is obtained from merchantable coal itself. In order to secure perfect combustion of this fuel, on account of the closeness

with which it packs, it is necessary that the draught of air should be greater than that required for burning larger sizes of coal. The ashpit beneath the fire is entirely closed, except at one place which admits the pipe through which the blast is forced. The bottom of the fire-box, instead of being a grate, is composed of perforated sheet iron, resting upon supports sufficiently strong to sustain it. The blast is produced by a small jet of steam forced through an orifice not exceeding the twentieth part of a square inch. This jet of steam, blown through the orifice, is introduced into a pipe which might be described in shape like the two frustrums of a cone, joined at their narrow diameters. The vacuum produced by this blast draws after it an enormous volume of air, which furnishes sufficient oxygen to consume the finest coal dust. The pipe leading the jet of steam to the orifice is controlled by a small valve which is held open by a spiral spring, and whenever the pressure of steam in the boiler rises to a certain height, say one hundred pounds to the square inch, it counteracts the force of the spiral spring, closes the orifice through which the steam escapes, and shuts the blast off completely from the fire; and whenever the steam in the boiler falls below the pressure of say seventy pounds to the square inch, the strength of the spring, overcoming the resistânce of the steam, opens the valve, and the blast is again introduced. There is generally one, but sometimes two or three, of these pipes introduced beneath the fire-box; and the inner surface of the larger diameter of the cone, which extends beneath the fire, is closed by a suspended valve which falls back whenever the blast ceases; so if there should be two or three of these pipes entering beneath the surface of one fire-box, and anything should happen to one, whereby the blast would be suspended, the valve would fall, and close the orifice so as to prevent the escape of the blast entering from the others. The whole apparatus is therefore very simple, and easily understood. We have obtained, after several months, not only of experiment, but of absolute trial, in stationary engines, a result from this waste fuel fully equal to that obtained from the most expensive quality of merchantable coal. The next trial after that with stationary engines was made upon a locomotive, and I think I may safely say that it has proved equally successful.

The fire-box of the locomotive engine is made precisely like that of the stationary boiler, the bottom being of perforated sheet iron. Of course you can see that if the ordinary exhaust of the engine was used to create the draft, its intensity would be so great as to draw

up all the finer particles of culm and carry them through the smoke-stack. The exhaust is, therefore, practically abandoned, except as I shall explain hereafter, and the blast produced by the steam jet is introduced beneath the surface of a perforated plate in the locomotive, the ash-pan or fire-box of which is closed at all places except that through which the blast enters. In order to utilize the heat of the escaping steam, as well as to prevent the intensity of the blast that would be produced by the exhaust, the steam, as it escapes from the cylinders, is taken through two series of pipes, one of which is in front of the boiler beneath the smoke-stack, and the other is placed horizontally upon the surface of the boiler, both being united and forming a condenser. The water pumped from the tender of the locomotive passes on its way to the boiler through this condenser, and the steam is utilized to heat all the water that enters into the boiler. After this, the steam is taken into an annular chamber around the centre of the smoke-stack, closed at the top, and, finding no vent there, is taken—at a distance of two or three inches from the top—by a six-inch pipe, downward through this chamber and ejected from below through a smaller orifice into the smoke-stack itself, thereby producing not a fitful and irregular draught like that of the exhaust, but a continued steady blast, which is essential to the combustion of this fuel in the locomotive engine. The water produced by the condensation of the steam escapes through a pipe leading downward from the bottom of the annular chamber. The experiments with stationary and locomotive engines having been successful, the next experiment will be made upon steamships, and you can readily see the difficulty that we may here encounter from the fact that so much more fresh water will be required on account of the increased quantity of steam used for the purpose of producing the blast of air. I can see, however, that this may be overcome, and I trust that no difficulty may attend the introduction of the process on board of steamships.

And now I should like to suggest to the members of this Institute, as something they may seriously think of, whether this vast amount of fuel, this forty million tons, heretofore comparatively worthless, and which, up to this time, its owners would have been glad to have given away, whether this vast amount of fuel cannot be made use of for the purpose of smelting iron ores in the blast-furnace, or of heating and puddling iron in the rolling mill. In the first place let me call your attention to this fact, which I omitted to state when I spoke of the results of the experiment for producing steam, that

from the ordinary coal dust, such as is usually thrown away at the mines, we obtained a heating power of such intensity that one pound of coal dust converted eight and a half pounds of water into steam; and, further than that, it is remarkable that from some piles of coal dust that have been exposed to the atmosphere for over forty years, some of them probably mixed with pieces of slate, which in that long time had crumbled into dirt, and therefore made the fuel more worthless than it would be if it had been nothing but pure coal, we obtained a heating power sufficient to evaporate six and a half pounds of water with one pound of fuel. Now, with such a result obtained, why should not this fuel be used in the manufacture of iron? Of course, with the reverberatory furnace, it could be used for generating gas. But I wish to throw out a suggestion to those who are better able to cope with the subject than I am, that probably some process could be adopted whereby iron ores of superior chemical qualities, but containing so small a percentage of iron as not to bear long transportation, might be reduced to the form of powder, and freed from such impurities as are capable of mechanical separation, so as to produce an ore elevated to the standard of 60 or 65 per cent. of metallic iron, which would bear the cost of transportation. This could be carried to the coal regions, there mixed with coal dust and some proper flux, and by compression formed into a block, to be thrown into a furnace, in order to produce pig iron at a very low cost.

Having thrown out these suggestions in the hope of attracting your attention, and leading some of your members to the solution of the problem which I have proposed, I now turn to the more pleasant part of the duty which has been assigned me to-night, and welcome you most cordially to the city of Philadelphia. Here in this old Quaker City, we have, as you know, one of the most perfect systems of common schools in the country. We have institutions of learning, respectable on account of their age, and venerable for the high character and great attainments of the professors who adorn them. We have academies sacred to the propagation of a taste for art and for music, and yet I will venture to say that no school nor institute, nor academy, is of greater importance to the development of the resources of the State of Pennsylvania, and to the prosperity of the city of Philadelphia, than the Institute I now have the honor of addressing. The prosperity of this State and its development, not only in manufacturing industry, but in that commerce which necessarily must be the attendant upon success in

manufactures, is dependent upon the mining industries within her borders.

Long since, I am glad to say, has the time gone by, when it was believed that an eminently practical man, armed with muscle, but devoid of brains, was alone essential to the solution of that great problem of how to contend with nature, in order to wrest from her embrace the mineral wealth that she has stored up beneath the surface of the earth, and it is now admitted that muscle must be directed by brains, and that scientific attainments of the highest order, such as are cultivated by the members of this Institute, are the first requisite in him who undertakes the charge of any important mining enterprise.

I bid you then God-speed in your good work, and I bid you a glad welcome to this city on this Centennial year, well knowing that among those interested in the results of your genius, your learning, your industry, and your skill, there is no community more benefited than the city of Philadelphia, on whose behalf I now welcome you within her borders.

At the conclusion of Mr. Gowen's address, President Holley said:

I am sure that I express the feelings of the members of the Institute, and also the sentiments of our guests, when I return to President Gowen our hearty thanks for his beautiful and eloquent words of welcome and encouragement, information, and instruction. There are so many suggestive thoughts in his remarks, especially in regard to the utilization of waste coal, that I can hardly refrain from starting a discussion on that subject now, and would do so if time permitted. But when time does permit I am sure that subject will be very fully and thoroughly discussed by the members of this Institute, as being one of the most important that could be brought before them, the pleasure and satisfaction in the discussion being enhanced by the careful and perspicuous way in which President Gowen has introduced the subject. The courtesies of President Gowen to the Institute in times past, and those which the programme leads us to believe that we shall experience during the present week and the week which is to come, are so conspicuous, that I might properly, and would gladly, devote the remainder of our time to-night in returning our acknowledgments to him. But, gentlemen, I must leave both of these subjects for another and most pleasant duty I have to perform, and that is, to announce to you, officially, the election this Centennial year, of the Honorable Abram S. Hewitt as President of

the Institute. Gentlemen, the election of Mr. Hewitt was one of those matter-of-course occurrences which spring out of a spontaneous feeling of fitness and propriety among the members of the Institute. A large experience at home has enabled him to deal with practical questions connected with the iron manufacture, and given him a great intimacy with those commercial and political considerations which affect metallurgy both as a profession and as a trade. His professional education and commercial qualifications, his traditions of leadership in all the enterprises in which he has engaged—all these things have had their influence in this election, and while Mr. Hewitt, in consequence, takes upon himself an additional honor, he confers an additional honor upon the Institute.

Gentlemen, Mr. Hewitt, the President-elect, will now address you.

(Mr. Hewitt's address appears among the papers of this meeting.)

At the conclusion of the address the session was adjourned, and Mr. Hewitt received the members and guests of the Institute at the Centennial headquarters, 1100 Girard Street.

The second session was held at the Judge's Hall, Centennial Exhibition grounds, on Wednesday morning, June 21st, at 10 o'clock.

After announcements in reference to excursions by Mr. E. B. Coxe, President Holley introduced Mr. I. Lowthian Bell, M. P., F.R.S., who read a paper on the Hot Blast, with an Explanation of its Mode of Action in Iron Furnaces of Different Capacities. At the conclusion of Mr. Bell's paper, Mr. Pechin, Vice-President, in the chair, said:

I am quite sure that I am speaking for every member of the Institute in expressing to our distinguished guest our satisfaction in having him here to-day to read this paper, and our hearty thanks to him for his extremely interesting and valuable contribution.

Our place of meeting has been an unfortunate one, owing to the confusions and interruptions. While we may regret that there has not been a better opportunity of listening to Mr. Bell, we can congratulate ourselves that his paper will very shortly be in print, where we can all read it. This paper is now open to discussion. We should be very glad indeed to hear an expression of opinion on the part of any gentleman connected with the Institute of Mining Engineers, or the Society of Civil Engineers, or our foreign guests.

Remarks were made by Messrs. Coxe, Alexander, and Egleston,

regretting the inability to discuss the paper of Mr. Bell, owing to the noises and interruptions. The session was then declared adjourned by Mr. Pechin.

On Wednesday evening a dinner was given by the members of the Institute to their foreign guests at Belmont Mansion, Fairmount Park.

On Thursday morning the Institute and invited guests assembled on a steamer, courteously placed at their disposal by the Philadelphia and Reading Railroad Company, and the day was passed on the Delaware River, stops being made at the company's coal wharves and ship-yards at Richmond, at the Girard Point elevators, and at Chester.

On Friday three sessions were held at the hall of the Franklin Institute, when the following papers were read:

Morning Session.—The Lead District of Southeastern Missouri, by Prof. G. C. Broadhead, of Pleasant Hill, Mo.

The Nomenclature of Iron, by Prof. H. Wedding, of Berlin.

Boracic Acid in Lake Superior Iron Ores, by Prof. Thomas Egleston, of New York.

Black-Band Ores of Ohio, by Prof. J. S. Newberry, of New York.

History of the Bessemer Manufacture in the United States, by R. W. Hunt, of Troy, New York.

Mr. E. B. Coxe called the attention of those present to the exhibition of a working model of a modern coal-breaker at 539 Chestnut Street, which gave a capital idea of the manner of hoisting, dumping, breaking, screening, and loading of anthracite coal. The agent of the model had given an invitation to the members of the Institute to visit the exhibition, and Mr. Coxe said it was a good opportunity for those unfamiliar with anthracite mining to see how coal was destroyed in Pennsylvania.

Mr. Oliver Evans Wood read to the Institute some interesting original documents with reference to the early use, by Oliver Evans, of anthracite coal in the melting of iron.

In the course of the discussion of Dr. Wedding's paper, Prof. Egleston offered a resolution that an International Committee, of which Mr. Holley shall be a member, be appointed to determine and limit the use of terms used in the nomenclature of iron and steel.

The resolution was adopted.

Afternoon Session.—The Endurance of Iron Rails, by W. E. C. Coxe, of Reading, Pa.

The discussion of Mr. Bell's paper on the Hot Blast, read at the Wednesday morning session.

Geological Explorations with the Diamond Drill, by L. A. Riley, of Ashland, Pa.

Composition of Flue-dust, by J. Blodget Britton, of Philadelphia.

The Mineral Wealth of Japan, by H. S. Munroe, of Brooklyn, N. Y.

Evening Session.—The Kind-Chaudron Process of Sinking and Tubbing Shafts, by Julien Deby, C.E., of Brussels, Belgium.

The Extraction of Zinc in a Blast Furnace, by F. L. Clerc, of Bethlehem, Pa.

Explosion of Fire Damp at the Midlothian Colliery, Va., by Oswald J. Heinrich, of Midlothian, Va.

On Saturday an excursion party started from the Philadelphia and Reading Railroad depot at 8.30 A.M. The first stop was at Phœnixville, where the Phœnix Iron Works, Clarke & Reeves's Bridge Works, Schuylkill Copper Works (Hunt & Douglas process), were visited. The train then passed over the Perkiomen and East Pennsylvania branches to Allentown, thence by the Lehigh Valley Railroad to Bethlehem, where the Bethlehem Iron Company's Steel Works and the Lehigh Zinc Company's Works were visited. The party then returned over the same route to Philadelphia.

On Monday, three sessions were held in the hall of the Franklin Institute.

Morning Session.—The following Annual Report of the Council was read and adopted:

In accordance with the rules, the Council reports to the Institute that during the past year three meetings have been held, to wit, in Dover, N. J., Cleveland, Ohio, and Washington, D. C. These meetings have been largely attended; the papers read, seventy in all, have been of great value; and the mines and works visited of professional interest.

168 new members have been elected, and 43 associates, also 3

foreign members—a total accession of 214. The membership of the Institute now comprises:

Honorary members,	4
Life members,	4
Foreign members,	41
Members and associates,	563
Total,	612

The Institute has lost by death six home and two foreign members—men whom the profession could ill afford to lose:

AUGUSTUS STEITZ, of St. Lous.
HOWARD PAINTER, West Chester, Pa.
CHAS. VON LIEBENAU, Silver City, Idaho.
A. J. BROWN, Treasure City, Nevada.
J. G. WITHERBEE, Port Henry, N. Y.
H. F. Q. D'ALIGNY, New York City.
ED BLACKWELL, London.
J. B. A. LORSONT, London.

The third volume of Transactions has been issued and distributed to members, and to scientific societies and libraries at home and abroad. A valuable library is accumulating through the exchanges of the Transactions with those of other scientific and technical societies. The report of the Treasurer shows the receipts for the year to have been $6493.98, and a balance on hand of $1428.24. The Council congratulates the Institute on the success of the work of the Centennial Committee, in providing headquarters for the Institute in Philadelphia, and for the admirable arrangements it has made for the convenience and entertainment both of the members and foreign guests.

The Secretary then read the following list of names which had been proposed for membership and associateship in the Institute, and approved by the Council. The gentlemen named were unanimously elected.

MEMBERS.

Allen, Charles F.,	Cincinnati, O.
Boyd, Charles R,	Wytheville, Va.
Brydges, Frederick H,	Phœnixville, Pa.
Burden, I. Townsend,	Troy, N. Y.
Caldwell, W. B.,	Louisville, Ky.
Carson, James P.,	New York City.

Champin, H.,	New York City
Chouteau, Pierre,	St Louis, Mo.
Clarke, T C.,	Philadelphia.
Claussen, Franz Fritz,	Pepperell, Mass.
Clerc, F L,	Bethlehem, Pa.
Colburn, Henry B,	Mine La Motte, Mo.
Crowther, Benjamin,	Sharpsburg, Alleghany Co, Pa.
Daniels, Fred. H,	Worcester, Mass.
Davis, O. W, Jr.,	Bangor, Maine.
Draper, Thomas W. M.,	New York City.
Edwards, J. Warner,	Philadelphia.
Ellsworth, A. M,	San Francisco, Cal.
Faunce, G. B,	Boston, Mass.
Fisher, Harvey,	Duncannon, Perry Co., Pa
Gill, John L., Jr.,	Pittsburgh, Pa.
Goodale, Charles W,	Marlboro', Mass
Gould, Robert H.,	East Cambridge, Mass
Hall, Edward J., Jr,	Buffalo, N. Y.
Herr, H. B,	Rosita, Colorado.
Hewett, George C.,	Jenkintown, Montgomery Co, Pa.
Hill, John W.,	Hamilton, O.
Hunt, Alfred E.,	Hyde Park, Mass.
Inman, Alvin L.,	Crown Point, Essex Co., N. Y.
James, Samuel, Jr.,	Cambridgeport, Mass
Kerr, Prof Wm. C,	Raleigh, N. C.
Knowles, Hon L J.,	Worcester, Mass.
Kudlich, Edgar,	Drifton, Luzerne Co., Pa.
Lamborn, Robert H., Ph D,	Philadelphia.
Leavitt, E. D., Jr.,	Cambridgeport, Mass.
Lee, Richard Henry,	Philadelphia.
Lockwood, G. P.,	Salt Lake City, Utah
McKee, Wm. W,	Philadelphia.
May, De Courcey,	Baltimore, Md.
Merry, Henry,	Negaunee, Marquette Co., Mich.
Patton, William Henry,	Virginia City, Col.
Proctor, John R.,	Lexington, Ky.
Ramsey, Richard,	Braidwood, Will Co., Ill.
Rand, Addison C.,	New York City.
Robinson, L. W.,	Philadelphia.
Robinson, Thomas W.,	Chicago, Ill.
Roe, G. G.,	Mineville, Essex Co., N. Y.
Roe, L. H.,	Port Henry, Essex Co., N. Y.
Schwarz, Theodore E.,	Boston, Mass.
Shaler, Prof. N. S.,	Cambridge, Mass.
Shockley, Wm. H.,	New Bedford, Mass.
Smith, Fillmore M.,	Syracuse, N. Y.
Snyder, John Fisher,	Scranton, Pa.
Strauch, George B.,	Pottsville, Pa.
Sussman, Julius H.,	Boston, Mass.
Sweet, John E.,	Ithaca, N. Y.
Thomas, James,	Oxmoor, Jefferson Co., Ala.

Townsend, Walter D.,	Ward District, Boulder Co, Col.
Whitehill, H. R.,	Carson City, Nevada
Wild, Henry Fearing,	Socorro, New Mexico
Wilson, John A,	Philadelphia.
Wilson, John L.,	Philadelphia.
Wrigley, Henry E.,	Titusville, Pa.

FOREIGN MEMBERS.

Althans, Oberbergrath Ernst F.,	Breslau, Germany.
Kupelwieser, Professor Franz,	Leoben, Austria.

ASSOCIATES.

Arnold, J. B.,	Pittsburgh.
Barros, Luiz de Souza,	School of Mines, New York City.
Cleveland, Orestes,	Jersey City, N. J.
Conzelman, Wm. Eliot,	St. Louis, Mo.
Denegre, Wm. P.,	Troy, N. Y.
Emerson, B F.,	Copper Falls, Keweenaw Co, Mich
Fellows, Walter Allen,	Philadelphia.
Keep, Wm. J.,	Troy, N. Y.
Powel, John H., Jr.,	Philadelphia.
Radford, W. H.,	School of Mines, New York City
Sax, John K,	Pittston, Luzerne Co, Pa.
Schwartz, J. E,	Pittsburgh
Willard, H. B,	Port Henry, Essex Co, N. Y.
Witherbee, Silas H,	New York City.

Prof. Frazer said: I intend to give notice at the proper time of a motion making a change in the rule of the Institute in regard to election of members. There is no doubt that most of the gentlemen named are unobjectionable, but the principle is bad to allow a large number to be taken in in this way. We know the Council are composed of competent men, but the system is too much like oligarchical government to suit my taste. I would propose that a list be made out of the candidates for membership, and that this be forwarded by the Secretary of the Institute to each of the members. An opportunity will thus be given for a more general and satisfactory vote.

Prof. Frazer offered the following resolution, which was unanimously adopted:

"*Resolved*, That the sincere thanks of the American Institute of Mining Engineers be tendered to the Philadelphia and Reading Railroad Company for the generous and intelligent assistance offered to it and its foreign guests during the present session, and to Mr. Franklin B. Gowen, the President of that company, through whom these facilities were extended."

In commenting upon the resolution, Prof. Frazer said that only one who, like himself, had worked upon one of the committees could appreciate the munificence and kindness of Mr. Gowen, and the small amount which could have been done by the Institute without the assistance of the Reading Railroad Company.

The following resolution was then offered and unanimously passed:

"*Resolved*, That the thanks of the Institute of Mining Engineers are hereby extended to the Franklin Institute for the use of its hall and buildings, to the Society of Civil Engineers, Academy of Natural Sciences, and other societies for courtesies extended, and to the Local Committee for their efficient and admirable services in securing the convenience and pleasure of the members and their guests."

Prof. Frazer said that he withdrew his notice of amendment to the rules, as he had since learned that the subject had already been considered by others, and that they had taken steps looking to that end.

Mr. J. B. Britton spoke of the desirability of issuing certificates of membership in the Institute, and wished the subject referred to a committee.

The Chairman remarked that the subject had already received earnest consideration in the Council, and that the feeling was rather averse to issuing certificates.

After some discussion, whether the subject should be referred to the Council or to a committee, Mr. Britton withdrew his motion.

Mr. J. B. Pearse subsequently renewed the motion, which was carried, that the Council be hereby requested to consider and report on the propriety of issuing certificates of membership.

Mr. J. S. Alexander, in the absence of the chairman of the Centennial Committee of the Institute, spoke of the finances of the committee. The original programme contemplated the raising of $5000. The sum of $4200 had been subscribed, which was insufficient to cover all the expenses of the committee. He appealed to those who had not already subscribed to assist the committee as liberally as they could.

The papers read and discussed at this session were:

The Iron Manufacture in the United States, by J. B. Pearse, of Philadelphia.

A Study of the Specular and Magnetic Iron Ores of the New Red Sandstone in York County, Pa., by Prof. Persifor Frazer, Jr., of Philadelphia.

The Reconstruction of a Furnace Crucible while in Blast, by J. H. Bramwell, of Quinnimont, West Virginia.

Roasting of Sulphurous Iron Ores in New Jersey, by C. H. Vannier, of Succasunna, N. J.

Water in Coals, by J. Blodget Britton, of Philadelphia.

Afternoon Session.—A paper on the Minerals of Southwestern Virginia was read by Mr. C. R. Boyd, of Wytheville, Va.

Mr. J. S. Alexander, of Philadelphia, exhibited some specimens from a newly discovered deposit of argentiferous and auriferous copper ore in Llano County, Texas.

This ore occurs in an east and west fissure vein, between well-defined wall-rocks, dipping at an angle of 45° towards the south. At the top the lead is seven feet, and at the bottom of the present exploring shaft (35 feet) it widens to ten feet. The ore occurs in veins and spurs diffused through white quartz, and increases in quantity with every foot of depth, but whether the present well-defined lode continues to any great distance, vertically or longitudinally, the limited exploration of course cannot determine. The richer parts of the lead is the Peacock ore of the miner, the Erubesite or Carnite of the mineralogist, and is reported, but by what analyst I am uninformed, to contain 35 per cent. of metallic copper and $120 in gold and silver. This new mineral district possesses an additional interest from the fact of being so far east of the meridian of heretofore wrought lodes containing the precious metals. The specimens before you are from a depth of 24 feet, and are not so rich as the ore found at 35 feet, of which, unfortunately, I have been as yet unable to receive specimens.

A profile drawing of the Sutro Tunnel, sent to the Centennial Rooms by Mr. Sutro, through one of the members of the Institute, Mr. James D. Hague, of San Francisco, was then shown by Mr. Alexander, who, in a brief sketch of the object and progress of that great engineering work, stated that up to June 1st, of the present year, 13,338 feet of the entire distance (about 20,000 feet) had been successfully accomplished; and that although many of the great Comstock mines were already approaching and pushing below the level of the tunnel (nearly 2000 feet at the Comstock Lode), which will preclude the possibility of a thorough drainage of the lode without pumping, the completion of the tunnel will, nevertheless, greatly facilitate the drainage by lessening the lift 2000 feet, and furnish, besides, a new and economical outlet for the ore. Mr. H. S.

Drinker, of Philadelphia, being called upon by Mr. Alexander, as the possessor of much detailed information, then gave an interesting account of the early history of the enterprise, together with statistics of progress.

Evening Session.—The papers read at this session were:

On the Manufacture of Forged Iron Car-wheels, by Prof. Adolph Henry, of St. Etienne, France.

A Study of Igneous Rocks, by Prof. Persifor Frazer, Jr., of Philadelphia.

The following papers were read by title:

Some Points in the Treatment of Lead Ores in Missouri, by Prof. C. P. Williams, of Rolla, Mo.

Palæozoic Strata in Huntingdon County, Pa., by C. A. Ashburner, of Philadelphia.

Deflection of Girders, by W. S. Ayres, of Trenton, N. J.

Composition of Silver-gray Iron, by Edward Hart, of Easton, Pa.

Some Things that affect the Production of Carbonic Acid in the Blast Furnace, by Charles Himrod, of Youngstown, Ohio.

Hematite Ore Mines East of the Hudson River, by J. F. Lewis, of Amenia, N. Y.

The report of the Committee on Railway Resistances was received and ordered to be printed.

Mr. Pechin then offered the following resolution, which was adopted unanimously:

Resolved, That the best thanks of the American Institute of Mining Engineers are hereby tendered to Mr. A. L. Holley, the retiring President of the Institute, for his most capable, energetic, and successful administration of the duties of his office during the past year.

After a brief reply by Mr. Holley, the Institute adjourned.

On Tuesday and Wednesday, June 27th and 28th, the members of the Institute and invited guests visited the Schuylkill coal regions of Pennsylvania, transportation and entertainment being munificently provided by Mr. Franklin B. Gowen, President of the Philadelphia and Reading Railroad.

The excursion party left the Philadelphia and Reading Railroad depot by special train, at 8.30 A.M. At Reading the car shops and rolling mill of the company were visited. The party then went, via

the Lebanon branch, to the Cornwall magnetic ore banks, near Lebanon; thence by the Lebanon and Tremont branch to Brookside Colliery, where time was allowed for inspecting the coal breaker. Pottsville was reached about 8 P.M., where a banquet was provided by the railroad company. On Wednesday the Norwegian shafts, sunk by means of the diamond drill, were first visited, then, returning to Pottsville, the party went by the way of the Mahanoy Planes, to the Tunnel Colliery near Ashland, where they were hospitably entertained by Mr. Lewis A. Riley, Superintendent of the Locust Mountain Coal Company. From Ashland the excursion returned via the Gordon Planes and the Mine Hill Railroad to Philadelphia. The excursion party numbered 216, and included among the foreign guests 11 from Germany, 10 from Austria, 8 from Sweden, 8 from the British Colonies, 6 from Great Britain, 6 from Belgium, 5 from Russia, 3 from France, 2 from Spain, 2 from Holland, 2 from Switzerland, and 1 from Siberia.

PHILADELPHIA MEETING,

October, 1876.

THE Institute assembled on Tuesday evening, October 24th, in the hall of the Franklin Institute, Mr. Frank Firmstone, Vice-President, in the chair. Mr. J. Price Wetherill, of Tremont, Pa., read a paper on An Outline of Anthracite Coal Mining in Schuylkill County, Pa. The paper was discussed by Messrs. Coxe, Rothwell, Heinrich, Harden, and Symons.

The second session was held on Thursday evening.

Mr. A. L. Holley, Chairman of the International Committee, appointed by the Institute to consider the nomenclature of iron and steel, offered the following report of the committee, signed by all the members:

WHEREAS, The recent production of soft, cast, malleable compounds of iron by the Bessemer, the Siemens-Martin, and the crucible steel processes appears to demand a new nomenclature of iron compounds, for the following reasons:

1st. The term "steel," by which these soft products are commercially and professionally designated in England and in the United States, does not completely distinguish them from previously existing "steel" which would harden and temper.

2d. A nomenclature recognized in all languages seems desirable, as well for commercial as for scientific purposes, especially as lawsuits, already commenced, depend on the meaning of the term "steel."

3d. Although homogeneity, due to fusion, is usually recognized, and is by this committee recognized as the most definite characteristic of both hard and soft steel, this quality may be equally well expressed in other terms, thus leaving the old term, "steel," to define the malleable compounds of iron, which will harden and temper.

Therefore, resolved, That this committee recommends the following nomenclature:

1. That all malleable compounds of iron with its ordinary ingredients, which are aggregated from pasty masses, or from piles, or from any forms of iron not in a fluid state, and which will not sensibly harden and temper, and which generally resemble what is called "wrought iron," shall be called WELD IRON (German, *Schweisseisen*; French, *fer soudé*).

2. That such compounds, when they will from any cause harden and temper, and which resemble what is now called "puddled steel," shall be called WELD STEEL (German, *Schweiss stahl*; French, *acier soudé*).

3. That all compounds of iron with its ordinary ingredients, which have been cast from a fluid state into malleable masses, and which will not sensibly harden by being quenched in water, while at a red heat, shall be called INGOT IRON (German, *Flusseisen;* French, *fer fondu*).

4. That all such compounds, when they will from any cause so harden, shall be called INGOT STEEL (German, *Fluss stahl;* French, *acier fondu*).

I. LOWTHIAN BELL,
DR. HERMANN WEDDING,
P. TUNNER,
RICHARD ÅKERMAN,
A. L. HOLLEY,
THOMAS EGLESTON,
L. GRUNER.

Mr. William Metcalf, of Pittsburgh, then read a paper entitled, Can the Present Commercial Nomenclature of Iron and Steel be reconciled to a Scientific Definition of the Terms used to Distinguish the Various Classes? The subject was then discussed by Messrs. Holley, Raymond, Howe, and others.

On motion of Mr. Raymond the report of the International Committee was accepted, and further action on it delayed until the next meeting of the Institute.

Mr. R. P. Rothwell read a paper on the Coal Production of the United States.

Mr. A. L. Holley offered the following resolution, which was unanimously adopted:

WHEREAS, The novel, wise, and useful design of the Centennial Committee of this Institute, and its most judicious and faithful execution in opening rooms in the city of Philadelphia, in furnishing them with a large and instructive collection of maps and publications; in organizing weekly *conversaziones;* in extending courtesies to all engineers; in furnishing information concerning localities, routes, and works to foreign guests; in bringing together inquirers from all parts of the world and the makers, managers, and owners of American machinery and engineering and metallurgical works, have been so conspicuously useful and agreeable to our foreign professional brethren especially, as to call forth from them a universal expression of gratitude, and a general determination to follow the example of the committee on similar occasions, in their own countries;

And whereas, The co-operation and courtesy, during the period of the Centennial Exhibition, of the Centennial Commission of the American Society of Civil Engineers, and of the members of that Society at large, with our own Centennial Committee, and with the members of this Institute at large, has not only facilitated the accomplishment of the results referred to, but has led to a wide acquaintance, and promoted the growth of a kindly feeling between the members of the two societies; therefore,

Resolved, That the sincere thanks and hearty congratulations of the Institute

are tendered to its Centennial Committee, for its valuable services to the guests of the Institute, and to the Institute itself, in promoting its objects and extending its influence;

Resolved, That the thanks of the Institute are especially due to the Secretary of the Centennial Committee, Mr. William G. Neilson, for his most thoughtful, courteous, and laborious services to its guests and members;

Resolved, That the Institute tenders its congratulations to the Centennial Committee of the American Society of Civil Engineers, not only with regard to the success of the work in which the two societies have co-operated, but in the belief that the acquaintance and good feeling developed during their agreeable labors will permanently establish such harmonious relations, and, from time to time, lead to such farther co-operation as will, in a still greater degree, benefit the two societies and the profession at large.

The third session was held on Thursday morning, when the following papers were read:

On the Volumetric Determination of Sulphur and Ammonia in Illuminating Gas, with a description of the apparatus employed, by H. E. Sadler and Prof. B. Silliman, of New Haven.

On a Plan for a Mining School in Japan, by Prof. H. S. Munroe, of Brooklyn, N. Y.

On the Effect of the Increased Height of Blast Furnaces, by H. M. Howe, of Boston, Mass.

Mr. Thomas Whitwell, of Stockton-on-Tees, England, in the discussion following Mr. Howe's paper, spoke of the effect of "superheated" blast.

Mr. R. W. Raymond, on behalf of the Centennial Committee, made the following statement and report of progress:

It is scarcely necessary to inform members of the Institute that the plan adopted by the Centennial Committee has been executed with a highly satisfactory degree of success. The headquarters in Girard Street, Philadelphia, have been kept open daily and nightly for the reception of members and guests, a large number of whom have registered their names and made frequent use of the facilities offered by the committee. The extent to which the rooms have served as a gathering-place for American and foreign engineers, may be inferred from the following analysis of the names recorded. It should be remarked, however, that the actual number of gentlemen visiting the rooms is larger than the registry indicates, since many have been present on various occasions who have not left their names. This is particularly the case with the attendants at the Thursday *conversaziones*, on which occasions the rooms have often been crowded.

The registry, up to October 25th, is as follows:

Nationality.	Number.	Nationality.	Number.
United States,	377	Switzerland,	2
Germany,	43	Italy,	2
France,	20	South America,	2
England,	19	Siberia,	2
Austria,	19	New Zealand,	1
Sweden,	19	Portugal,	1
Belgium,	15	Norway,	1
Canada,	13	Mexico,	1
Russia,	7	Cuba,	1
Spain,	4	Poland,	1
Australia,	3		
Netherlands,	3	Total registry,	556

The extent to which foreign engineers have been assisted in their examinations of the resources and industries, mines and works, of the country by the agency of the Centennial Committee, may be partially inferred from the statistics of correspondence. The copy-books of the headquarters show, besides 432 general letters, no less than 394 letters of introduction, given mostly to foreign guests, and addressed to members in all parts of the country. In addition to these, many letters of a similar character have been written by members of the committee and others, but not recorded at the headquarters. It is a moderate estimate to say that more than 500 such written introductions and recommendations (to say nothing of the innumerable personal introductions taking place at the rooms) have been furnished through the agency of the Institute and its committee, and particularly through the very efficient activity of Mr. Neilson, the secretary. The committee desires to bear witness also to the extremely cordial reception everywhere encountered by the bearers of such recommendations. The unanimous testimony of our foreign guests amply confirms this declaration. Besides letters, Mr. Neilson has furnished, to individuals and parties, 41 complete route-schedules, including all the directions and information needed by strangers travelling for the first time in the United States. Some of these parties have made very extensive tours, embracing even the distant regions of the Pacific Coast, and they report that the advice and assistance thus furnished to them have been of the greatest use in securing economy of time and completeness of satisfaction and comfort.

Every Thursday evening throughout the season has been devoted to an informal meeting or *conversazione;* and on every such occa-

sion, with a single exception, there has been, in addition to the social interchange of opinion, an address or familiar talk, usually followed by a discussion, upon some interesting topic of mining, civil, or metallurgical engineering. At the next meeting of the Institute, when the Centennial Committee will make its final report, a list of these topics will be included. For the present, it is sufficient to refer members to the files of the *Engineering and Mining Journal*, in which the *conversaziones* have been briefly reported. The committee desires, however, on this occasion, to acknowledge with thanks the cordial co-operation of the Centennial Commission and private members of the American Society of Civil Engineers, whose presence and contributions have done much to enhance the attractiveness of our rooms and the interest and pleasure of our social gatherings. The harmonious operation of the two societies, and the happy arrangement by which our members were invited to make use of the headquarters of the Civil Engineers in the Centennial Exhibition (this courtesy being reciprocated by us at our headquarters in the city), have secured for all the advantages of both plans. Your committee recognized, as I had the honor, speaking in its name at the Cleveland meeting, to declare that certain arguments undoubtedly favored the establishment of a headquarters for the Institute within the Centennial grounds, yet it was moved by many considerations, which experience has now justified, to choose a different plan. We owe it to the friendly courtesy of the Civil Engineers that our own scheme has been amply successful, while we have not lost thereby even the benefits which we feared its adoption would necessarily sacrifice; yet the committee is assured that the advantages of this arrangement have been mutual, so that the sense of cordial alliance and common success, rather than of obligation on either side, characterizes the present relations of the American Society of Civil Engineers and the American Institute of Mining Engineers.

The response of the professional gentlemen, for whose convenience the plan of your committee was largely designed, has been enthusiastic and flattering, and at last, proceeding from words to deeds, it has taken a form unexpected to the committee and almost overwhelming. The first manifestation of the kind was a communication from the Imperial German government, thanking the Institute for the courtesy and assistance tendered to its engineers, and presenting, as a testimony of its appreciation, the splendid collective exhibits of the German silver and lead works and the salt mines, now in the Centennial Exhibition, together with a valuable series of

maps and publications. This magnificent gift has been followed by the offer of the exhibits of ores from Switzerland; of the Luxemburg Mine and the Saarbrücken Furnace Company; of the Fagersta collection of Swedish irons and steels, including the famous samples covered by the Kirkaldy tests, and of the exhibits of a considerable number of American mining and metallurgical companies. Intimation has also been made to the committee that portions of the exhibits of Austria, Mexico, Portugal, Spain, Queensland, Victoria, and South Australia are ready for the acceptance of the Institute.

The Centennial Committee, surprised by the first of these donations, and forced by circumstances—which it is not necessary to give on this occasion in detail—to take immediate action, would have been compelled to decline all gifts of this kind, but for the timely offer of the trustees of the Pennsylvania Museum and School of Industrial Art to set apart a suitable room in Memorial Hall (which is to be permanently occupied by that institution) for the reception and installation of the collections given to the Institute of Mining Engineers, and to assume the care of that apartment without cost to the Institute, for such a period as the collections should be permitted to remain, the ownership and control of the Institute over them to be unimpaired.

This offer the Centennial Committee provisionally accepted; and this acceptance, together with that of the collections tendered, has been reported to the Council, and will doubtless be brought before the Institute for ratification. Your committee considers this arrangement as most fortunate, and trusts that it will be approved by the Institute.

With reference to the receipts, assets, and expenditures connected with the Centennial Headquarters, the committee considers itself responsible to the subscribers to its special fund; but, as a matter of general interest to a large number of members, begs to say briefly that the amount subscribed and collected is about $4000, and that this sum, together with the proceeds of the assets on hand at the rooms, will suffice to cover all expenses hitherto incurred or now foreseen. But many members have expressed the strong desire that the books, maps, and pictures collected at the rooms should remain the property of the Institute. To effect that end, a further sum of about $250 will be required; and if this is contributed by members, the committee will take pleasure in transferring to the Institute the valuable library and collection now at the rooms. Subscriptions for the purpose may be sent to Mr. Neilson. I will add, that it seems

not only a pity but a shame to scatter this collection; since many books and publications, though solicited and obtained by the committee for the rooms specially, were undoubtedly expected by the donors to become permanently the property of the Institute. Your committee does not doubt that the funds necessary to preserve them will be easily collected.

Mr. Firmstone, Vice-President, then offered, on behalf of the Council of the Institute, the following resolutions:

Resolved, That the Institute accepts the collections and publications presented to it as reported hitherto, and the Council is authorized to accept in its discretion such as may hereafter be presented, and to conclude the provisional arrangement pending with the Pennsylvania Museum and School of Industrial Art, for the installation of the said collections, and to do whatever else is necessary in the premises, provided, that the right of property and control of the Institute over these collections shall not be impaired, and that the Institute shall not be involved in pecuniary obligations, or in payments from the fund consisting of members' fees, and the proceeds of the sale of Transactions.

Resolved, That the thanks of the Institute be tendered to the generous donors of collections and publications, and to the trustees of the Pennsylvania Museum and School of Industrial Art.

After discussion by Messrs. Pearse, Frazer, and Raymond, the resolution was unanimously adopted.

The fourth and concluding session of the Institute was held on Thursday afternoon. Mr. A. L. Holley read a paper by Mr. C. M. Ryder, of the Otis Iron and Steel Works, Cleveland, on the Determination of Carbon by Magnetic Tests.

The following persons, having been duly proposed and indorsed by the Council, were then elected members, or associates, of the Institute:

HONORARY MEMBER.

Richard Åkerman,	Stockholm, Sweden.

MEMBERS.

John Bogart,	New York City.
Fred. Everett Bruen,	Newark, N. J.
Robert Bunsen,	Boulder, Col.
W. E. C. Eustis,	Readville, Mass.
Fred. M. Gordon,	Ironton, Lawrence County, Ohio.
George N. Gray,	Huntington, Cabell County, W. Va.
William G. Hamilton,	New York City.
James Amory Herrick,	Nashua, N. H.
R. F. Hoke,	Raleigh, N. C.
Joseph L. Hunter,	Philadelphia.

William Kent,	Hoboken, N. J.
Gabriel Leverich,	New York City.
Oliver Matthews,	Burlington, Wis.
F. H. Oliphant, Jr.,	Pardoe, Mercer County, Pa.
John N. Pott,	Tremont, Schuylkill County, Pa.
F. B. F. Rhodes,	Drifton, Luzerne County, Pa.
Charles M Ryder,	Cleveland, Ohio.
Samuel Thomas,	Columbus, Ohio.
John Fraser Torrance,	Montreal, Canada
Edwin A. Wetmore,	Marquette, Mich.
George T. Wickes,	Selma, Allegheny County, Va.
Ed. H. Williams, Jr.,	Drifton, Luzerne County, Pa.
John I. Williams,	Pittsburgh, Pa.
Dr. Otto Wuth,	Pittsburgh, Pa.

ASSOCIATES.

Benjamin F. Chynoweth,	Rockland, Mich.
James B Mackintosh,	Hoboken, N. J.
Frederick N. Owen,	Nyack, Rockland County, N. Y.
Nelson W. Perry,	School of Mines, New York City.
Holmes E. Sadler,	New Haven, Conn.
Milton S. Thompson,	Islip, L. I., New York.
F. Von Cabeen,	Philadelphia.

FOREIGN MEMBERS.

Lucien Arbel, Senateur,	Rive de Gier, Loire, France.
Joseph Fayn,	Liége, Belgium.
Prof. Adolph Henry,	Rive de Gier, Loire, France.
Prof. Hans Höfer,	Klagenfurt, Austria.
Prof. Nicholas Jossa,	St. Petersburg, Russia.
Ferdinand Valton,	Paris, France.

Mr. R. W. Raymond made two short communications on the Production of Bessemer Steel and Petroleum in California.

Mr. H. M. Howe offered the following resolution:

Resolved, That the hearty thanks of the American Institute of Mining Engineers are hereby offered to the management of the Franklin Institute for its courtesy in placing the hall at the disposition of the Institute for the present meeting.

The following papers were then read by title:

The Lignite Coals of Colorado, by Prof. W. B. Potter, of St. Louis, Mo.

The Mineral Industry of Russia, by Dr. R. W. Raymond.

Notes on the Method of Preparation of Zinc Oxide, by Prof. C. P. Williams, of Rolla, Mo.

The meeting was then adjourned

NEW YORK MEETING,

February, 1877.

THE opening session of the Institute was held at the rooms of the American Society of Civil Engineers, No. 4 East 23d Street, Vice-President R. W. Raymond in the chair.

After a short introductory address by the chairman, the following names were presented by the Council for election as members and associates of the Institute. They were unanimously elected:

MEMBERS.

Abbott, James W.,	Lake City, Col.
Abbott, J. J , Jr.,	Lake City, Col.
Bartlett, J. C.,	Cambridge, Mass.
Billings, G. H.,	Boston, Mass.
Blake, Frank C.,	Lafayette College, Easton, Pa.
Dewey, Fred P.,	Lafayette College, Easton, Pa.
Douglass, Samuel T.,	Ann Arbor, Mich.
Emmons, S. F.,	New York City.
Engle, George U.,	Philadelphia.
Harrington, Dr. Bernard J.,	Montreal, Canada.
Hayden, Wm. B.,	Columbus, O.
Hill, Leslie C.,	Capelton, Quebec, Canada.
Land, W. J.,	Atlanta, Ga.
May, Wm. A.,	Scranton, Pa.
Mills, James E.,	St. Louis, Mo.
Moore, Charles W.,	Montezuma, Ind.
Page, William Byrd,	Lexington, Ky.
Putnam, Douglas, Jr.,	Ashland, Ky.
Richards, Henry,	Dover, N. J.
Roberts, Percival, Jr.,	Philadelphia.
Sackett, S. G.,	Brooklyn, N. Y.
Schley, Wm. S.,	Atlanta, Ga.
Setz, Gustav,	Mine La Motte, Mo.
Talbutt, John H.,	Lexington, Ky.
Torrey, Herbert G.,	U. S. Assay Office, New York City.
Wernlitz, Fred. W.,	Cartersville, Bartow Co., Ga.
Wiestling, Geo. B.,	Mont Alto, Franklin Co., Pa.

FOREIGN MEMBERS.

Nicolsky, Prof. L.,	School of Mines, St. Petersburg, Russia.
Pourcel, Alexandre,	Chef de Service des hauts fourneaux et aciéries de Terre Noire, Loire, France.
Rolland, G.,	Ingénieur au Corps des Mines, Paris, France.

ASSOCIATES.

Corning, Frederick G.,	Freiberg, Saxony.
Dwight, George S.,	New York City.
Fairchild, A. C.,	Lafayette College, Easton, Pa.
Ferris, Lemuel P.,	Philadelphia.
Flickwir, David W.,	Philadelphia.
Floyd, Fred. W.,	School of Mines, New York City.
Fuller, J. T.,	Lafayette College, Easton, Pa.
Gay, Samuel,	Shenandoah, Schuylkill Co., Pa.
Genth, Frederick A., Jr.,	Philadelphia.
Griffiths, Howard B.,	Philadelphia.
Guiterman, Franklin,	Freiberg, Saxony.
Harper, Orlando M.,	Pittsburgh, Pa.
Harrison, R. B.,	Lafayette College, Easton, Pa.
Hasegawa, Yoshinosuke,	School of Mines, New York City.
Hemingray, William,	Shamokin, Pa.
Jordao, José Nabor Pacheco,	School of Mines, New York City.
Lyman, Frank,	School of Mines, New York City.
Marshall, Benjamin,	Sandusky, O.
McIntire, H. M.,	Lafayette College, Easton, Pa.
Mathez, Auguste,	School of Mines, New York City.
Meeker, R. A.,	Lafayette College, Easton, Pa.
Pettit, Henry,	Philadelphia.
Pierce, Wm. Ide,	School of Mines, New York City.
Smythe, R. M.,	School of Mines, New York City.
Stoiber, Edward G.,	Freiberg, Saxony.
Strieby, William,	School of Mines, New York City.
Strong, M. H.,	Brooklyn, N. Y.

The chairman then read the following resolutions that had been sent in to be submitted to the Institute:

Resolved, That the American Institute of Mining Engineers believes that system of Technical Education to be best which combines, as far as possible, theory and practice.

Resolved, That the American Institute of Mining Engineers believes that system of Technical Education to be best in which one or more years of practice is made to follow theory.

Resolved, That the American Institute of Mining Engineers believes that sys-

tem of Technical Education to be best in which one or more years of practice is made to precede theory.

Resolved, That the Congress about to assemble be memorialized by the Council of the American Institute of Mining Engineers (or by a committee specially appointed for the purpose) to make immediate provision for a creditable representation of mining and metallurgy of the United States in the Paris Exposition of 1878, by the appointment of a commission to take the matter in hand.

WHEREAS, Efforts are being made to secure Congressional legislation to secure in the near future the uniform adoption of the metric system of weights and measures in use in prominent European countries; therefore

Resolved, That the American Institute of Mining Engineers heartily indorse such action, and request the Council to take such action in the premises as it may deem best to express the favor with which the Institute would receive such legislation.

Resolved, That the Secretary be instructed to recommend members to use the metric system in all papers read before the Institute as far as practicable.

The chairman ruled that these resolutions were out of order, stating that this course was taken for the purpose of bringing the whole subject of the competency of the Institute to pass such resolutions fully before the Institute, and of obtaining an expression of its will. He stated the principle of the ruling to be that the Institute, under its rules and according to its nature, could not declare opinions or take or recommend action on any subject outside of the conduct of its own proceedings and publications.

Mr. E. C. Pechin, for the purpose of getting the decision of the Institute, appealed from the ruling.

The chairman then stated the grounds of his decision in substance as follows:

1. The objects of the Institute are declared in Rule I to be the promotion of certain ends by certain specified means, viz.: "Meetings for social intercourse, the reading and discussion of papers, and the circulation by publications of the information thus obtained." Rule VII declares, moreover, that "the Institute is not, as a body, responsible for statements of fact or opinion advanced in papers or discussions at its meetings." *This applies to all such statements whether advanced by one member or by a majority, or by the whole number of the members present at any meeting.*

2. The nature of the Institute necessitates this prohibition. Its largest meetings do not contain a majority of its members and associates; and the rules are intended to protect absent members and associates from being committed even in appearance to the opinions indorsed by the majority of those who happen to compose the audience at any one session.

3. The Institute contains between 600 and 700 members and associates, representing many different branches of the sciences and arts connected with mining and metallurgy. Perhaps no subject could be named with regard to which all these gentlemen would be able or willing to express as experts a decisive judgment. A body so constituted ought not to be asked to address to the public authoritative expressions of opinion.

4. On subjects merely of technical character, and, still more, on recommendations addressed to the public, to Congress, etc., there may be differences of opinion within the Institute. Discussion of such matters for information and for social enjoyment may be legitimate; but attempts to decide them by vote are manifestly injurious to both these objects, because the first object—information—requires that questions shall not be *settled,* but *kept open,* while the second object—social enjoyment—requires that the contests of parties shall be avoided.

5. Under this ruling, resolutions referring to our own publications and proceedings are admissible. Thus, we may recommend the use in papers and debates of the metric system, just as we may choose a certain style of type, or a certain place of meeting. But we cannot recommend legislation, or express general judgments as the opinions of this body.

6. Some precedents have been established at previous meetings of the Institute which bear against this ruling. Those precedents passed at the time unquestioned because the attention of the members was not called to their bearings, and the subjects to which they referred were subjects on which the opinion of those present was unanimous. But they are believed to have been, nevertheless, in violation of the rules and proper policy of the Institute. In the present case the Chair individually approves most of the resolutions offered, and for that reason is the more willing to establish, once for all, if sustained by the Institute, a precedent which will prevent the necessity of debating more objectionable propositions hereafter.

Mr. Pechin remarked that he fully agreed with the ruling of the chairman, and had appealed from the ruling to call forth the foregoing remarks.

After some further remarks by Messrs. Egleston, Frazer, and Birkinbine, the ruling of the Chair was sustained.

Mr. Raymond announced the programme of the meeting as arranged by the Local Committee of Arrangements, after which a paper by W. M. Courtis, of Wyandotte, Michigan, on The North Shore of

Lake Superior as a Mining District, was read by the Secretary. This paper was abundantly illustrated by mineral specimens.

Mr. E. B. Coxe, chairman, made the following final

Report of the Centennial Committee.

At the regular meeting of the Institute, held at New Haven, Connecticut, in February, 1875, the following resolution was adopted:

"*Resolved*, That the Council be authorized to renew to the Iron and Steel Institute of Great Britain, and to extend to other foreign professional societies or their members, the cordial invitation of the Institute to take part in our May meeting of 1876, and that the meeting of May, 1876, be held at Philadelphia; and that the Council be authorized, in view of the Centennial Exhibition, to make such arrangements for the said meeting as may conduce to the comfort of the members and guests and to the interest and value of the sessions."

The Council then appointed Mr. Eckley B. Coxe, Prof. Thomas Egleston, Mr. John S. Alexander, and Dr. R. W. Raymond a committee (with power to add to their number) to carry out the proposed plan. The committee organized by the selection of Mr. Coxe as chairman and Mr. Alexander as Treasurer and Temporary Secretary. Mr. William G. Neilson was subsequently added to the committee, and was elected Permanent Secretary.

The programme originally proposed by the committee, and which, with some slight modifications, was carried out, is shown by the following extract from the first circular issued by the committee:

"The object of the committee has been to devise a simple, practicable, and useful programme, neither ostentatious nor likely to intrude upon ground occupied by other societies, and at the same time capable of such expansion as circumstances may indicate and means permit.

"1. The committee will ask of the Institute, at the next (October) meeting, a vote authorizing the adjournment of the annual meeting of May, 1876, to the third Tuesday of June, the adjourned session to be held in Philadelphia.

"2. The committee will endeavor, by special invitations, to secure the attendance at the Philadelphia meeting of English and Continental mining engineers and metallurgists, and, if practicable, to give to the meeting an international character.

"3. The committee propose to engage suitable rooms in Philadelphia for the period of the Exposition, to furnish them with technical periodicals and books of reference concerning the resources

and industries of the United States, to secure the attendance of a competent secretary, and to keep these rooms open, day and evening, as the Centennial Headquarters of the American Institute of Mining Engineers. The practical object of this measure will be to afford to members and associates a place for social reunion, for writing and receiving letters, and for obtaining information or introductions. Foreign visitors interested in mining or metallurgy would, on making themselves known to the committee, receive cards entitling them to the privileges of the rooms, and particularly to the services of the Secretary in charge, who would be able to assist them in any line of inquiry which they might wish to pursue, giving them statistics, general information, directions, advice, and letters of introduction to all parts of the country. The same cards would entitle them to take part in the proceedings or excursions of the Institute.

"The addresses and prospective movements of members or visitors could be posted in books kept for the purpose, and letters could be forwarded to them regularly or friends advised of their whereabouts.

"The committee estimates that the sum of $5000 will be ample for the purposes of rent, furnishing, lighting, stationery, care of rooms, and salary of attendant secretary."

The members of the Institute were asked to subscribe, and when sufficient funds had been raised the committee engaged rooms at 1123 Girard Street, Philadelphia, and invitations were sent to a large number of kindred professional societies, to foreign government officials and periodicals, the object being to make known to the profession abroad what the Institute proposed to do. All the foreign correspondence was taken charge of by Prof. Egleston.

The following is a copy of one of the letters sent, and is a type of all:

School of Mines, Columbia College,
Corner Forty-ninth Street and Fourth Avenue,
New York, January 19th, 1876.

Dear Sir: The Committee of the American Institute of Mining Engineers, having in charge the reception of foreign mining engineers and metallurgists coming to this country to visit the Centennial Exposition, has perfected its arrangements, and has secured rooms at 1123 Girard Street, Philadelphia, which will be open to the members and guests of the Institute from April 1st to December 1st, 1876. These rooms will be in charge of a secretary of the committee, and will be furnished with all the technical periodicals, with conveniences for writing, and parlors for meeting and conversation. An address book will be kept by the Secretary for recording the names and addresses of all the members of the Institute, and of foreign engineers and metallurgists who come to the Exposition. All members of the profession, with introductions to the Institute or

its members, will receive cards which will entitle them to all the privileges of the rooms, and of attendance and participation in the meetings of the Institute.

The Annual Meeting, which usually takes place in May, has been postponed to the last of June, in order that we may have the pleasure of having the largest possible number of foreign engineers present. It will be held in the Jury Pavilion of the Exposition.

The committee propose to give conveniences at the rooms for the storage of baggage, specimens, and packages, which its guests may have collected in any part of the country, and desire to have kept in a safe place until they are ready to take charge of them. They also propose to prepare schedules of information relating to the leading mining and metallurgical industries of the country. In case any one should desire to pursue a special line of inquiry, the Secretary or the members of the committee will take great pleasure in forwarding such investigation. It is designed also for those members of the profession who have but a short time to remain, to group for survey the special objects which they may have an interest in studying in the Exposition. The Secretary is instructed to furnish to those who desire to make the acquaintance of specialists in this country, letters of introduction, which will secure for them, not only admission to the works which they desire to visit, but also the acquaintance of technical gentlemen in all parts of the country. We hope in this way to furnish to our foreign guests not only special information, but also to put them in the way of getting at a general survey of the whole of the mining and metallurgical industries of the United States.

The Institute will be greatly obliged to you if you will make these statements known, as far as it is in your power, to the mining and metallurgical engineers of your country, and we shall be pleased to have you personally give letters of introduction to us to any of your countrymen who may desire special information.

The members of the committee are: Eckley B. Coxe, Esq., J. S. Alexander, Esq., Dr. Thomas Egleston, and Dr. R. W. Raymond.

Yours very truly,

THOS. EGLESTON.

TO THE PRESIDENT OF THE IRON AND STEEL INSTITUTE, ENGLAND.

The response to the circular to members calling for subscriptions was cordial and liberal, and, as is shown by the financial statement appended, all the funds required were obtained.

The committee as soon as possible gave its attention to the formation of a library of reference, and contributions of books and pamphlets were solicited.

A large and valuable collection of geological and industrial works was thus obtained through the liberality of members and friends of the Institute, and by the expenditure of about four hundred dollars to fill out the gaps, which were to be expected in a collection of books and maps made up entirely of contributions, the committee was enabled to form a very valuable and complete library of reference.

The American Society of Civil Engineers having made arrangements to offer to its own members and to foreign engineers similar facilities in the Main Exhibition Building, the committees of the two societies agreed to work in concert, and under this arrangement members of the Institute were invited to avail themselves of the facilities offered by the American Society of Civil Engineers at the Exhibition, and our rooms were thrown open to its members in the same manner as to our own. This combination was productive of the most happy results, and added greatly to the efficiency of our arrangements.

A set of rooms, consisting of three rooms on the first floor, one on the second, and storage in the cellar, having been secured at 1123 Girard Street, on February 1st, 1876, the following circular was issued.

CENTENNIAL COMMITTEE, AMERICAN INSTITUTE OF MINING ENGINEERS,
No. 206 South Fourth St. (after April 1st, 1876, No. 1123 Girard St.), Philadelphia.

The city rooms of the Institute, at 1123 Girard Street,* Philadelphia, will be open day and evening, from April 1st to December 1st, 1876, for the use of members and associates, and of other persons, citizens or foreigners, properly introduced. Arrangements are also in progress to secure a headquarters for the Institute within the Centennial grounds; but the special purposes of the city rooms are such as could not be so well served by accommodations exclusively in the Exhibition.

These rooms are intended to be:

1st. A centre of social reunion for all members and associates in the city.

2d. A convenient resort for foreign engineers, metallurgists, geologists, etc., desirous of meeting their American colleagues, or of obtaining information and assistance in their study of American resources and industries.

3d. A repository of statistical and other information concerning the mining, metallurgy, geology, and geography of the United States, which can be consulted by members or guests, in connection with the study of these subjects in the Exhibition.

4th. An agency and directory for the convenience of members and guests in arranging tours, forwarding letters, storing packages, etc.

To carry out these plans, the committee has secured, at the above address, a suite of apartments, comprising three rooms on the ground floor, a room in the second story, and a room for storage in the basement. These will be suitably furnished and attended, and provided with the daily journals, scientific periodicals, geological and professional reports, maps, portfolios of drawings of machinery, descriptions of works, guide-books, railway tables, etc., for consultation; besides which, the Secretary will be prepared to furnish information, advice, and letters of introduction to members or guests interested in special lines of professional inquiry, whether in the Exhibition itself or in the country at large. It is probable that besides the ordinary social and professional use of the rooms, meetings for informal discussions will be held in them on one or two evenings of each

* About May 1st, the committee moved to more commodious quarters at 1100 Girard Street.

week. A register of the addresses and movements of members and guests will be kept, so that the present or prospective address of each may be known at any time. If it shall prove desirable, a copy or abstract of this register, or so much of it as shall show the addresses from day to day of mining engineers, metallurgists, geologists, etc., present in the city, will be kept at the headquarters of the Institute in the Exhibition. In connection with this registry, the committee will receive and forward letters, and store baggage, specimens, etc., at the order of their owners—these facilities being extended to all members and associates of the Institute, and others who shall have become entitled by proper introduction to the privileges of the rooms.

ECKLEY B. COXE,
THOMAS EGLESTON,
J. S. ALEXANDER,
R. W. RAYMOND,
WILLIAM G. NEILSON,
Committee.

On April 1st the committee took possession of its rooms and opened them for the use of the members and guests. The attendance from the first was good, and increased steadily, so that during the height of the Exhibition the rooms were often filled to overflowing.

It was decided that after the Exhibition had opened, an informal meeting or *conversazione* should be held every Thursday evening, at each of which a gentleman eminent in some department of civil or mining engineering, or in science, should be asked to give a short informal address.

These meetings were very successful from the first. They were largely attended, and were continued without interruption until after the Exhibition closed. Among those who addressed the members at the *conversaziones*, were Sir Redmond Barry, Chief Justice of Victoria, I. Lowthian Bell, M.P., Dr. Hermann Wedding, Julien Deby, Dr. T. Sterry Hunt, Dr. J. Lawrence Smith, Prof. Raphael Pumpelly, Prof. J. P. Lesley, Prof. William P. Blake, W. S. Keyes, C. W. Jenks, Major J. W. Powell, Thomas C. Clarke, Col. William Milnor Roberts, William J. McAlpine, Prof. E. T. Cox, Dr. R. W. Raymond, and A. L. Holley.

A number of monographs on important mining regions were prepared, in order to make visits to these regions more interesting and profitable.

That the invitations extended to both foreign and American engineers were appreciated, and that the facilities offered by the Institute were freely used, the register of names kept at the rooms abundantly shows.

Of the 610 names on the register, there were from Germany, 51; England, 23; Sweden, 21; France, 20; Belgium, 18; Austria, 18; Canada, 15; Russia, 8; Australia, 5; Spain, 4; Netherlands, 3; Switzerland, 2; Italy, 2; South America, 2; Siberia, 2; New Zealand, 1; Norway, 1; Cuba, 1; Poland, 1; Newfoundland, 1; and from the United States, 409. This list does not include many who attended on Thursday evenings.

The work of the committee, which was at once the most pleasant, the most laborious, and perhaps the most appreciated, was the furnishing of information to those gentlemen from abroad who wished to visit particular points of interest in the country. There were furnished to foreign guests 493 written letters of introduction, besides cards, and 43 detailed schedules of journeys, accompanied with maps of the United States, with the routes marked upon them.

The committee has received from abroad a large number of letters of congratulation and thanks from individuals, societies, and governments, in some instances accompanied by gifts of valuable mining and metallurgical collections in the Exhibition. A list and description of these collections will be found in the report of the Museum Committee.*

The total amount received from subscription was $4158.45, which was expended as follows:

Rent of rooms and gas,	$1268 64
Salaries,	1579 33
Books, maps, binding, etc.,	428 92
Furniture,	249 84
Printing and stationery,	259 80
Postage,	180 50
Newspapers and incidental expenses,	191 42
	$4158 45

All the books, papers, maps, etc., which were not considered as belonging to the Museum Committee, were sent to the library of the Society, at Easton, Pa.

The committee cannot close its report without thanking its Secretary, Mr. William G. Neilson, for the energy, ability, and fidelity with which he discharged his onerous duties; and also Mr. Edward

* Since the above was written, the Emperor of Germany has presented Mr. Neilson, the Secretary of the committee, with the decoration of the Royal Order of the Red Eagle, fourth class.

Nichols, who, from April 1st to December 1st, 1876, was the assistant secretary, and ably assisted Mr. Neilson in all his duties.

Mr. J. S. Alexander, chairman of the Museum Committee of the Institute, made a verbal report on the organization and work of the committee. Owing to the fact that the Institute had been presented with a large number of valuable collections, it became necessary to appoint a committee to attend to their reception and installation. The committee appointed by Council consisted of J. S. Alexander, chairman, Prof. J. P. Lesley, Prof. Thomas Egleston, Messrs. A. L. Holley, William Sellers, William Metcalf, and William G. Neilson. Subsequently, Mr. C. A. Young was appointed to Mr. Neilson's place as secretary. The committee had made favorable arrangements with the Pennsylvania Museum and School of Industrial Art for the installation and display of the collections in Memorial Hall.

The following is the complete list of the contributions to the Museum:

GERMANY.

	PRESENTED BY
1. Collection of specimens from the different lead and salt works of the Prussian Government, with cases, maps, drawings, statistics, etc.	The Imperial Minister for Trade and Commerce, through Dr. Hermann Wedding, Royal Counsellor of Mines, Berlin.
2. Case containing ores, fuels, and sections of rolled iron.	The Luxembourg mine and Saarbrücken Furnace Company, Burbach, through the same.
3. Case containing ores, fuels, pig and rolled iron; *suite* of hydraulic forgings and boiler head.	Mr. A. Borsig, Berlin, through the same.
4. The Siegerland collective exhibit of iron ores and spiegel iron, together with maps, drawings, etc.	The exhibitors, through Mr. William Bruegman.
5. Ores and spiegel iron.	The Westphalian Union, through Messrs. Thomas Prosser & Son, New York.
6. T-rail test and two glass cases, containing steel turnings from large cannon.	Fried. Krupp, Essen, through Mr. Alfred Nonne, Engineer.
7. Case containing iron tests.	Friedrich Wilhelm Hüttee, Troisdorf, through Messrs. Peter Wright & Sons, Philadelphia.

SWEDEN.

8. Magnetic iron ores, ingot, bar, and manufactured steel, gun-barrel tests, and a valuable series of samples, covered by the tests of David Kirkaldy, of London.	Mr. Christian Aspelin, Director of the Fagersta Steel Works, Westanfors, Sweden, through Mr. C. Juhlin Dannfelt, Royal Swedish Commissioner, and Mr. E. Bruesewitz, Royal Mint, Stockholm.
9. Ores, fuels, fluxes, slags pig, and bar iron, and steel, together with suite of rock specimens, and a map illustrating the geology of the iron districts of Sweden.	The Jernkontoret (Iron Master's Association), embracing the following works, etc.: Osterby-Strömbacka Bruksegare. S. Löfvenskold, Nissafors. P. M. Larsson, Rallso̊. A. von Stockenström, Åker. Ankarsrums Bruksegare. Björneborgs Bruksegare. Larsbo-Norns Aktiebolag. Hofors-Hammarby Bruksegare. Stora Kopparbergs Bergslag. Grefve C. von Hermanson, Ferna. Laxå Bruks Aktiebolag. Carl Ekman, Finspong. Avesta-Garpenbergs Aktiebolag. New Gellivare Company. C. A. Rettig, Kilafors. Surahammars Bruks Aktiebolag. Schisshyttans Bruks Aktiebolag. Ramnås Bruks Aktiebolag. Albert Robson, Aspa. J. O. Sundström, Charlottenberg. Kohlsva Bruksegare, through Prof. Rich. Åkerman.
10. Ores and pig and bar iron.	Uddeholm Works, through the same.
11. Ores, pig and bar iron, and steel.	Bofors Works, through the same.
12. Wheels and axles, bar iron, and railway axle tests.	Surahammer Works, through the same.
13. Flags, drapery, etc.	Royal Swedish Commission.

RUSSIA.

14 Collection of ores, charcoal, fluxes, cast iron, and specimens covered by assays and ordnance tests, together with drawings of blast furnace, from the Alexandrowski and other works in the district of Olonetz.	Gen. C. de Bielsky, Com.-Genl., and Prof. L. Nicholsky, Commissioner.
15. Steel gun ring, disk turned from end of cannon, conical shell, etc., from the Perm Gun Foundry.	The same.

16. Thirty-two specimens of copper ores, slags, black copper, and purified copper, from the Bogoslof Copper Smelting Works.	The same.
17. Twenty-two specimens of iron ores, graphites, and coals, with analyses, collected by the Russian Government.	The same.
18 Twenty-seven specimens of copper ores and their rocks, from the mines of Turnisk and Trolofsk, in the district of Bogoslovsk, Ural Mountains.	The same.
19. Twenty specimens of the iron ore, etc., from the mines and quarries of Mt. Blagodat, used in the Imperial Russian Works of the district of Goroblagodatsk.	The same.
20 Cast iron and slag from the Verkhni-Turinsk Works.	The same.
21. Zinc ores, galena, fire-clay, sheet zinc, etc., from Poland.	The same.
22 Series of copper and iron ores, slags, etc , together with specimens of pig and bar iron, black copper, matte, pure copper, crucibles, fire-brick, etc., illustrating the metallurgy of copper and iron as practiced at the Demidoff Works.	Prince Paul Demidoff, through Gen. C de Bielsky, Com.-Genl., and Messrs. David Thomson & Co , Agents, New York.
23 Specimens of the coals of South Russia.	Capt. Scmetschkin, Imp. Russian Navy.

SPAIN.

24. Coal, iron ore, and galena.	Col. Juan J. Marin, Eng. Corps, and Don Alvaro de la Gandara, Royal Spanish Commissioners.

PORTUGAL.

25. Ores of copper, antimony, tin, lead, and zinc, together with samples of marbles and building stones.	Prof Lorenço Malhiero, Portuguese Commissioner.

AUSTRIA.

26. The Carinthian collection of iron and lead ores, together with specimens of pipe, wire, bullets, etc., made from lead obtained by the Carinthian process.	A. Jugovitz, Kagenfurt, through Dr. Migerka, Austrian Commissioner-General.

ITALY.

27. Manganiferous iron from Monte Argentario, Tuscany.	Messrs. Rae Bros , Leghorn, through Messrs Robert Taylor & Co., Agents, Philadelphia.

BELGIUM.

28. Specimens of zinciferous galena	Count d'Oultremont, Commissioner.

ENGLAND.

29 Model of blast-furnace, with group of Whitwell hot-blast stoves and drawings illustrating the same	ThomasWhitwell,Esq ,Stockton-on-Tees.
30. Case of models, illustrating the Siemens regenerative gas furnaces, together with specimens of steel, iron, glass, etc., produced in these furnaces.	Dr. C. Wm. Siemens, London, through Messrs Richmond & Potts, Agents, Philadelphia.
31. Case containing section of submarine cables.	Messrs. Siemens Bros , London, through Mr. Richard Borchers.
32. Case containing samples of bleaching and potters' clays.	Messrs Robert Dunn & Co., St. Austell, Cornwall, through Messrs. Dunn Bros., Philadelphia.
33. Cases containing samples of coal and iron.	Wigan Coal & Iron Co., through Messrs. Peter Wright & Sons.
34. One steel armor plate two inches (2″) thick; one do. eight inches (8″) thick; one do. eleven inches (11″) thick; one do. twenty-two inches (22″) thick, together with two pieces of heavy steel turnings and signs.	Messrs. Charles Cammell & Co., Sheffield, through Messrs W. Bailey Lang & Co., Agents, New York.

VICTORIA.

35. Collection of ores and publications.	Sir Redmond Barry, President of Commission.

SOUTH AUSTRALIA.

36. Iron and copper ores and building stones.	S. Davenport, Esq., Commissioner.

TASMANIA.

37. Ores and other minerals.	H. P. Welch, Esq., Commissioner.

QUEENSLAND.

38. Ores and building stones.	A. Mackay, Esq., Commissioner.

CANADA.

39. Suite of rocks and ores of Canada.	Prof. A. R. C. Selwyn, Director of the Geological Survey of Canada.
40. Iron sand, bloom and bar iron.	Moisie Iron Co., Montreal.
41. Large case of graphite in its natural and varied manufactured forms, together with one large mass weighing four thousand eight hundred and seventy pounds (4870 lbs.), in separate cases.	Dominion of Canada Plumbago Company, Ottawa, Ont.

NOVA SCOTIA.

42. Collection of ores.	Dr. Honeyman, Commissioner.

NEW ZEALAND.

43. Ores and coals.	New Zealand Commissioners.

BRAZIL.

44. Fuels, ores, building stones, bloom iron, etc.	Dr. J. M. de Silva Coutinha, Commissioner.

MEXICO.

45. Argentiferous galena.	Prof. Mariano Barcena, Commissioner.

UNITED STATES OF AMERICA.

46 Case containing samples of coals, ores, pig iron, and slag.	Rockhill Coal and Iron Company, Philadelphia.
47. Samples of fuel, ore, pig and manufactured iron, Martin steel, wire, etc.	Messrs Cooper, Hewitt & Co., New York City.
48. Bessemer converter bottom and fire-brick.	A. J Haws, Esq., Johnstown, Pa.
48½. Samples of fire-brick.	Scioto Fire-brick Co., Sciotoville, Ohio.
49. Case containing collection of coals, ores, limestones, and clays found along the line of the P. & R. R. R. and lines controlled by the same, together with counter containing samples of manufactured iron from the P. & R. R. R. Co.'s rolling-mill.	Philadelphia & Reading Railroad Co.
50. Large mass iron ore, together with specimens of ore and limestone.	Shelby Iron Co., Alabama.
51. Set of oil-well tools.	Messrs. Blakslee Bros., Foxburg, Pa.

52. Case containing collection of test specimens of wrought iron and steel made by the Henderson process and covered by tests of David Kirkaldy, London.	James Henderson, Esq., Hamburg, Pa.
53 Ores, fuels, and fluxes, together with drawing of blast-furnace.	Bay Furnace, Onata, Lake Superior.
54 Large case containing fuels, ores, fluxes, and pig and manufactured iron.	Lehigh Valley Centennial Committee (William Firmstone, Esq., Chairman), representing the following companies: Bethlehem Iron Co., Carbon " " Saucon " " Crane " " Lehigh " " Thomas " " Glendon " " Andover " " Coleraine " " Pennsville " " Emaus " " LehighValley " " Allentown " " Durham Iron Works, Catasauqua Manufacturing Co., Allentown Rolling Mill Co.
55. Ores, coal, limestone, and sections of rolled iron.	Union Rolling Mill Company, Buffalo, N. Y.
56. Coal, bar and sheet iron, and large map of the Mahoning Valley block-coal basin.	Mahoning Valley Centennial Association (Homer Hamilton, President), Youngstown, Ohio.
57. Cast of Colorado Cañon.	Maj. J. R. Powell, U. S. G. & G. Sur.
58. Two large maps of Pennsylvania anthracite region.	R. P. Rothwell, Esq., New York.
59. Iron ore.	Lake Superior Iron Co.
60. Case of samples of steel.	Messrs. Sax & Kear.
61. Case containing specimens of marbles, slags of copper, and pure copper.	Messrs. Pope, Cole & Co., Baltimore, Md.
62 Table made of anthracite coal.	P. B. Cunningham, Esq , Allentown, Pa., through Messrs. Dreyer, Simpson & Co.
63 Lead, iron, and zinc ores from Missouri.	Missouri State Board of Centennial Managers.
64. Bog iron ore.	The Katahdin Iron Company, Bangor, Maine.
65. Show cases containing specimens of crucible steel and tools and other articles made therefrom.	Messrs. Miller, Metcalf & Parkin, Crescent Steel Works, Pittsburgh, Pa.
66. Frame containing complete samples of the Mt Savage fire-bricks.	Union Mining Comhany, Alleghany, Md.

67. Specimens of the minerals of the State of Arkansas.	W. E. Rowell, Esq., State Centennial Agent.
68 Case containing ores, limestones, etc.	Chester Iron Company, Philadelphia, Pa.
69. Collection of coals, iron and copper ores from Tennessee and North Carolina.	Gen. John T. Wilder, Chattanooga, Tenn.
70. Case containing samples of coal for the manufacture of illuminating gas.	Penn Gas Coal Company, Philadelphia, Pa.
71. Steel tires, ingot, axle, and twisted rail.	Midvale Steel Works, Philadelphia, Pa.
72. Case containing coal from Clearfield County, Pa.	Kittaning Coal Company, Philadelphia, Pa.
73. Sections of arch of St. Louis bridge; also steel links and column.	Keystone Bridge Company, Pittsburgh, Pa.
74. Samples of Connellsville coal and coke	Messrs. J. M Cochran & Co., Uniontown, Fayette County, Pa.
75. Chrome ore and steel.	Chrome Steel Co., Brooklyn, N. Y.
76. Witherbee's patent tuyere.	American Society Civil Engineers.
77. Ores and coals from Kentucky and the Hanging Rock, Ohio, region.	Messrs. Traber & Aubrey, Cincinnati, Ohio.
78. Sandstone from Valley of the Red Bank, Pa.	William P. Shinn, Esq , Pittsburgh, Pa.
79. Coals, ores, and building stones, from Wisconsin.	Professor Sweet, State Geological Survey.
80. Coals and ores from Kentucky.	Prof. J. R. Proctor, State Geological Survey.
81. Minerals along the line of the Central Pacific Railroad.	Mr. J. L. Scupham, Centennial Agent of the Central Pacific Railroad.
82. Specimens of Siemens-Martin steel, test bars, flanging, etc.	Otis Iron and Steel Co., Cleveland, Ohio.
83. Specimen of block coal from Staab Mine, Spencer County, Indiana.	John S. Alexander, Esq., Philadelphia, Pa.
84. Magnetic iron ore.	Hussey & Howe Mining Co., Plattsburg, New York.

DEPOSITS.

1. One steel armor plate eight inches (8″) thick; one do. nine inches (9″) thick; one do. fourteen inches (14″) thick, together with signs and railing.	Messrs. John Brown & Co., Sheffield, through Messrs. Naylor & Co., Philadelphia, Pa.
2. Case of tests, Landore-Siemens steel.	British Admiralty.
3. Model of Pernot furnace plant.	Messrs. Cooper, Hewitt & Co., New York City.
4. Model of Lucy furnace plant.	Lucy Furnace Co., Pittsburgh, Pa.
5. Case containing collection of manganiferous iron ore, limestone, and pig iron.	Woodstock Iron Co., Anniston, Ala.
6. Case containing sections of rolled iron, together with test specimens.	Passaic Rolling Mill Co., Paterson, N. J.

The second session was held on Wednesday morning at the School of Mines, Columbia College.

Prof. H. S. Munroe exhibited two specimens of prehistoric Japanese bells, and described their discovery and the speculations as to their real character and use.

The chairman, Dr. Raymond, read a paper on Ferro-Manganese, by W. P. Ward, of Cartersville, Ga.

The chairman then announced that the special order of this meeting was the motion of Mr. Holley at the previous meeting to adopt the report of the International Committee on the Nomenclature of Iron and Steel.

The discussion was opened by Mr. H. M. Howe, and was participated in by Messrs. Park, Metcalf, Raymond, Hunt, Egleston, Frazer, Coxe, and Barnes. After a prolonged and animated debate* the following resolutions were adopted:

Resolved, That the thanks of the Institute be tendered to the members of the International Committee on the Nomenclature of Iron and Steel, for the zeal, intelligence, judgment, and harmony with which they have considered the subject referred to them.

Resolved, That the report of the International Committee on the Nomenclature of Iron and Steel be recommitted to the Committee, with the suggestion that some other term be substituted for the term *weld;* and that, without expressing any opinion concerning the preamble reported by the International committee, the Institute recommends to its members to use hereafter in papers and discussions before this body the nomenclature proposed by the committee, except the part hereinbefore recommitted for suggested alteration; it being understood that the ingot-iron and ingot-steel of this classification constitute, taken together, what is now commercially known as cast steel, including the so-called low or soft cast-steels.

THIRD SESSION.—After a recess, during which the members were afforded an opportunity to inspect the laboratories and collections of the School of Mines, and to partake a lunch hospitably supplied by Prof. Egleston, the Institute reassembled at 4 o'clock.

Dr. P. De P. Ricketts exhibited an electrical phenomenon with an analytical balance. By rubbing the glass case the balance was thrown out of adjustment, which could be restored by discharging the electricity of the glass. The possibility of errors in analysis resulting from this cause was apparent.

The status of Mr. F. N. Holbrook was changed from associate to member, on recommendation of the Council.

* The debate will be found in connection with Mr. Howe's paper.

The following papers were then read:

On the Goderich Salt Region, by Dr. T. Sterry Hunt, of Boston.

On the Trias in Eastern America, by Prof. Persifor Frazer, Jr., of Philadelphia.

Note on the Cost of Bessemer Rails, by P. Barnes, of New York.

On Wednesday evening a *conversazione* of the Society of Civil Engineers and the Institute of Mining Engineers was held at the rooms of the former, when the subject of the introduction of the metric system of weights and measures as the legal standard of the country was informally discussed, Messrs. Wood, Briggs, Paine, Rothwell, Roberts, Brooks, Frazer, and Raymond taking part in the discussion.

FOURTH SESSION.—The Institute met at the rooms of the Society of Civil Engineers on Thursday morning, at half-past ten.

The chairman reported the following resolutions from the Council for adoption by the Institute:

Resolved, That the Council be authorized, in its discretion, to provide for the adjournment of the May meeting, after counting the ballots and without the transaction of other business, to a later day in the summer.

Resolved, That the Secretary, before sending out the nominations for officers, consult, as far as practicable, with the persons nominated and their proposers, so that the names of persons who could not serve, if elected, need not be submitted to the members.

WHEREAS, The Institute already comprises a considerable number of foreign members; and

WHEREAS, It is desirable that in the publications of the Institute permanent and universally intelligible units of measurement should be employed; therefore

Resolved, That members be recommended to employ. as far as practicable, in papers and debates, the metric system of weights and measures; and that the Secretary be instructed to add to papers and debates, before publication, the metric equivalent of the terms employed, wherever these have been omitted.

The above resolutions were unanimously adopted.

The following notifications of proposed changes in the Rules, to be acted on at the annual meeting, were then announced:

By Frank Firmstone, to amend Rule II as follows: Strike out the sentence beginning, "Each person desirous of becoming a member or associate," etc., and insert instead, "Each person desirous of becoming a member or an associate shall be proposed by at least three members or associates, and, if approved by the Council, shall be voted for by ballot as follows: Not more than two weeks after the adjournment of each regular meeting, the Secretary shall send to each member and associate ballots containing the names of all candi-

dates for admission who have been approved by the Council since the meeting next preceding. Members who wish to vote shall do so by returning their ballots to the Secretary. At the next regular meeting all ballots received by the Secretary shall be examined by three scrutineers (of whom the Secretary may be one), to be appointed by the presiding officer at the first session, and they shall report the result of their examination before the adjournment of the meeting. Three or more negative votes shall exclude from admission. Any person admitted shall become a member on the payment of his first dues."

Also, to amend Rule V by striking out "two scrutineers," and inserting "three scrutineers."

By Prof. F. Prime, Jr., to amend Rule II as follows: Strike out the sentence beginning "Each person proposed as an honorary member," etc., and insert: "Each person proposed as an honorary member shall be recommended by at least ten members or associates, and approved by the Council. The person thus recommended shall be voted for at the next general meeting after that at which the approval of the Council is made known to the Institute, and three negative votes shall be sufficient to prevent election; *Provided*, that the number of honorary members shall not exceed twenty."

Also, to change the sentence in Rule II—"Provided that honorary members, and members and associates permanently residing in foreign countries, shall not be entitled to vote or to be members of the Council," so as to read: "Provided that honorary members shall not be entitled to vote or to be members of the Council."

Also, to amend Rule III by striking out the clause, "and members and associates permanently residing in foreign countries, excepting Canada, shall be liable to such annual or other payments only as the Council may impose, to cover the cost of supplying them with publications."

Also to amend Rule IV by striking out the paragraph beginning "The Council elected under the former rules of the Institute," down to "hereinbefore provided."

Also, to change the paragraph in Rule IV from "or the Council may, by a vote of a majority of all its members, declare the place of any officer vacant on his failure for one year," etc., to read: "and the Council *shall* declare the place of any officer vacant on his failure for one year," etc.

By E. B. Coxe, to amend Rule IV so as to read: "The affairs of the Institute shall be managed by a Council, consisting of a Presi-

dent, nine Vice-Presidents, and fifteen Managers," etc., instead of six Vice-Presidents and nine Managers, as at present.

By Prof. Persifor Frazer, Jr., to amend Rule V by inserting "In case the number of names which remain on a ballot exceeds the number of offices to be filled, the requisite number of unstricken names shall be selected in the order of their occurrence on the list, and the ballot shall be assumed as cast for these names."

By Dr. T. M. Drown, to amend Rule V by substituting five weeks for thirty days, in the clause, "Nominations may be sent in writing to the Secretary . . . . . at any time not less than thirty days;" and by substituting four weeks for two weeks in the clause, "and the Secretary shall, not less than two weeks before the said meeting, mail to every member and associate," etc.

The following papers were then read:

On American Students of Mining in Germany, by J. C. Bartlett, of Cambridge, Mass.

On the Atlanta District, Idaho, by J. E. Clayton, of Salt Lake City.

On the Allouez Mine, and Ore Dressing as practiced in the Lake Superior Copper District, by C. M. Rolker, of New York.

Major T. B. Brooks exhibited and described a simple, portable, solar compress for use in exploring in magnetic regions.

Dr. T. M. Drown exhibited a specimen of basic sulphate of iron which had been formed in a flue in a coal mine, which, in the fresh condition, so nearly resembled coal as to have led to the supposition that coal-dust had in some way become consolidated to coal. An analysis was given of the deposit.

Dr. Raymond exhibited a sample of carbonate of iron from one of the Durham mines in Pennsylvania, and spoke of the diverse origin of limonite beds as suggested by the two specimens just exhibited.

The following papers by Mr. J. H. Harden, of the University of Pennsylvania, were read by title:

The Hollenbach Shaft, Wilkes-Barre, Pa.

Shaft Sinking and Salt Mining at Goderich, Canada.

Chart of the Coal and Iron Production in the United States from 1820 to 1876.

On motion, the Secretary was instructed to express in writing the thanks of the Institute to the various societies and individuals for courtesies received.

On Thursday afternoon a number of the members visited the

East River Bridge, and were received by the engineers in charge, and afforded full opportunity for examination of the process of construction.

On Thursday evening the Institute were invited to a reception at the house of Edward Cooper, Esq.

Fifth Session.—The concluding session of the Institute was held at the Stevens Institute of Technology, at Hoboken, on Friday morning at eleven o'clock, when the following papers were read:

On Ferro-Prussiate Paper for copying drawings, by Ogden Haight, of New York.

On the Economy of Pumping Engines, by John Birkinbine, of Philadelphia.

Note upon Methods of Drawing Metric and other Scales on Engineering Plans, by P. Barnes of New York.

A supplementary paper on the Determination of Carbon by Magnetic Tests, by C. M. Ryder, of Cleveland, Ohio.

On a New Form of Pinch Cock for Chemical Analysis, by H. E. Sadler, of New Haven, Conn.

Mr. J. D. Weeks, of Pittsburgh, spoke of the confusion existing at present in regard to wire gauges, and of the desirability of having a uniform wire gauge.

At the conclusion of Mr. Weeks's communication, Prof. Egleston suggested that before any proposal was made towards the adoption of a metric wire-gauge in this country, inquiries be made as to the gauge used for this purpose in France.

This proposal meeting with general favor, Prof. Egleston moved that the Chair appoint a committee for the collection of information as to the practicability of a legal standard wire-gauge in the United States.

The Chair subsequently appointed Messrs. Egleston, Weeks, and Metcalf.

The following papers were read by title:

Notes on a Mill Campaign at Hall Valley, Colorado, by J. L. Jernegan, of La Grange, California.

Franklinite of Franklin Furnace, by J. C. Platt, Jr., of Waterford, N. Y.

The Use of Coal Waste, by J. F. Blandy, of Philadelphia.

Commercial Analyses of Furnace Gases, by Prof. T. Egleston, of New York.

Technical Education, by Prof. L. M. Haupt, of Philadelphia.

Specific Gravity of Certain Leads, by Prof. C. P. Williams, of Rolla, Missouri.

Alloys of Iron with Certain Metals, by G. H. Billings, of South Boston, Mass.

Calculation of Heat Requirements, and Gas Analyses, by T. F. Witherbee, of Port Henry, N. Y.

Determination of Carbon in Iron and Steel, by A. S. McCreath, of Harrisburg, Pa.

Mr. J. D. Weeks offered the following resolution:

Resolved, That permission be granted to the editors or accredited representatives of any responsible journal to copy in whole or in part, or to make an abstract of any paper read before the Institute, under such regulations for the care and safety of the same as the Secretary may prescribe.

Dr. Raymond said that a contract now existed between the Institute and the *Engineering and Mining Journal* whereby the latter was obliged to publish all the papers before the Institute in full, and that if other journals were permitted to make selection among the papers and publish the most interesting in advance of the *Engineering and Mining Journal,* the editors would consider it a violation of the contract now existing.

After further explanation by Dr. Raymond and Mr. Weeks, and a general discussion, the resolution was rejected.

The Chairman then announced that the laboratories and workrooms of the Stevens Institute, including the testing department of the United States Test Board, were open for the inspection of the members of the Institute, under the guidance of the officers of the Stevens Institute. President Morton had also kindly invited the members to dinner, after which omnibuses would take any members who wished to visit the new tunnel under Bergen Hill, now in process of construction by the Delaware, Lackawanna & Western Railroad.

Resolutions were passed expressing the hearty thanks of the Institute to President Morton and the Professors and Trustees of the Stevens Institute, after which the Institute adjourned.

Secretary's and Treasurer's Statement of Receipts and Disbursements, from May 26th, 1876, to May 21st, 1877.

Balance at last statement,	$1428 24
Received for dues from members and associates, . . .	5430 00
Received for one life membership, ...	100 00
Received from sale of Transactions, ...	292 51
Interest, ...	30 00
	$7280 75

Subscriptions to Engineering and Mining Journal, including postage, ...	$1830 27
Extra copies of Journal sent to Authors and Secretary, .	64 88
Illustrated Supplements to Journal, ...	133 25
Printing and binding Vol. IV Transactions, ...	1464 97
Printing and binding Discussions on Technical Education, ...	179 34
Composition for Vol. V Transactions, ...	70 25
Printing Rules and Lists of members, ...	54 50
Printing Circulars, ...	63 25
Engraving, ...	675 18
Binding 50 copies each of Vols I, II, and III, . .	112 50
Binding of exchanges, . .	45 80
Stenographic reports of meetings, ...	287 67
Postage, ...	251 21
Freight, expressage, etc., . .	81 57
Incidental expenses, . . .	63 25
Salary of Secretary, . . .	1200 00
Balance, ...	702 86
	$7280 75

PAPERS.

[*The papers are arranged alphabetically, according to authors, under the respective meetings.*]

PHILADELPHIA MEETING.

JUNE, 1876.

DEFLECTION OF GIRDERS.

BY W. S. AYRES, C.E., TRENTON, N. J.

I AM well aware that this subject is not strictly in the line of mining engineering, yet as it is a subject with which mining engineers at times have something to do, I have thought, perhaps, it might not be wholly out of place to communicate to the Institute something of the method used in determining deflection, and of its final issue.

Having felt a need of some simple formula for determining the deflection of girders of uniform cross-section under any load, I have been led through the counsel of Mr. Frederick J. Slade, to whom I am indebted for many suggestions, to undertake a labor of which I shall in this paper give only some of the most important features.

The results arrived at agree with those obtainable from the received formulæ of Weisbach, Rankine, and others, but the expressions given by these authors, and by all others that I have at hand, are of such a form that they are not easily applied by those whose higher mathematics have become rusty from disuse, and they require, moreover, too much labor in their application to be of practical value.

The general formula that I have adopted is similar to that given by Rankine, and is deflection $= \frac{mWl^3}{EI}$, in which l is the span, W the total load, E the modulus of elasticity, I the moment of inertia of the uniform cross-section of the girder, and m a factor depending for its value on the mode of distribution of the load. The problem then is to find the value of this factor m in the formula, and for some distributions of the load it leads to a number of mathematical difficulties.

In this place I shall consider first the girder to be loaded symmet-

rically with two loads, and second, as loaded at any point with only one load. Consider the half span of any girder to be divided into 20 equal parts, and loaded with two loads successively applied at corresponding points of both halves of the span; then finding the complete integral of the expression $\frac{l-a}{2l^4} \cdot \int_o^c \int_o^c \frac{M}{Mo} \cdot dx^2$, between the limits $x = o$ and $x = c$, the point of greatest deflection, for each of these points we will have the respective values of m for each. The values of m thus determined for two loads are given in the accompanying table. For beams symmetrically loaded, the point of greatest deflection is, of course, at the centre of the span.

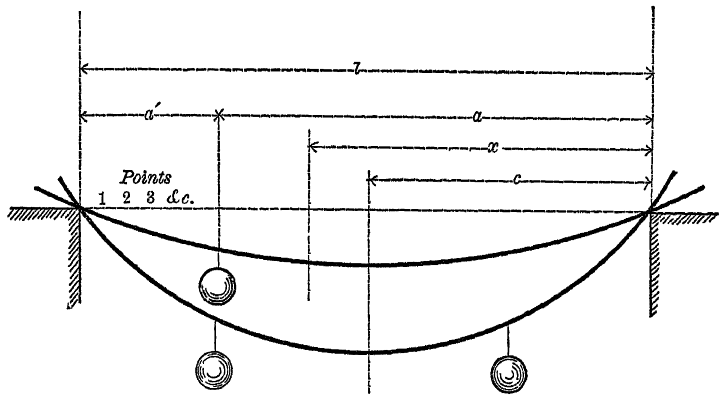
The values of the factor m for one load only are set in the table opposite the corresponding points of application for two loads, and are determined by finding the complete integral of the expression $\frac{(l-a)a}{l^4} \cdot \int_o^x \int_o^x \frac{M}{Mo} \cdot dx^2$ between the limits $x = o$ and $x =$ the point of greatest deflection for each of the 20 points of the half span. In this case the point x of lowest deflection is not at the centre of the span, but is at some point between the centre of the span and the load itself.

To determine this point is not easy, but after some labor it was found that $x = \sqrt{\frac{(2l-a)a}{3}}$. It was also found that the expression for the deflection in this case could be reduced to the general form, *deflection* $= \frac{W(l-a)}{EIl} \cdot \frac{x^3}{3}$, in which $x =$ the expression just given. If a, the point of application of the load, becomes equal to $\frac{l}{2}$, then this formula reduces to that of a single load applied at the centre, viz., *deflection* $= \frac{W l^3}{48 E I}$, which expression is at once obtained from the general formula above given by substituting for m its value found opposite point 20 in the table, viz., $.020833 = \frac{1}{48}$.

After the deflection and point of lowest deflection were determined by calculation for each of the 20 points of the half span, experiments were made with beams, and the actual and calculated results for these 20 points were, I may say, exactly the same.

It will be seen from a comparison of the factors m for corresponding points, remembering that when the beam is under two loads, W has twice the value which it has when the beam is under one load, that the deflection under one load for point 20 or the centre of the span, is, as it should be, just 50 per cent. of that produced by two loads, for point 10 is 50.8 per cent., and for point 1 is 51.3 per cent., and is not just half, as is sometimes supposed.

Another interesting feature, although it scarcely needs any proof, resulting from the demonstration is, that for a beam symmetrically loaded with two loads, and then still farther with additional loads,



the total deflection produced is equal to the sum of the deflections produced by the different sets of symmetrical loads taken separately.

I would add that some interesting and beautiful curves are also among the results of this double integral.

Example.—If it is required to find the deflection of a beam under a single load W, at say $\frac{1}{4}$ of the span, first find the value of $\frac{40a}{l} = 10$; then opposite point 10 in the table the value of m is found to be .014558, so that the deflection $= \frac{.014558\ \mathrm{W}\ l^3}{\mathrm{E\,I}}$.

TABLE.

Point loaded $= \frac{40a}{l}$	2 loads. m	1 load. m			2 loads. m	1 load. m
0	.000000	.000000		11	.015455	.015679
1	.001561	.001602		12	.016500	.016706
2	.003115	.003196		13	.017452	.017634
3	.004652	.004771		14	.018302	.018456
4	.006167	.006319		15	.019043	.019165
5	.007650	.007832		16	.019667	.019755
6	.009094	.009299		17	.020165	.020221
7	.010491	.010715		18	.020531	.020559
8	.011833	.012068		19	.020756	.020764
9	.013113	.013352	Centre of span	20	.020833	.020833
10	.014323	.014558				

ON THE HOT BLAST, WITH AN EXPLANATION OF ITS MODE OF ACTION IN IRON FURNACES OF DIFFERENT CAPACITIES.

BY I. LOWTHIAN BELL, M.P., F.R.S.

THERE has been probably no improvement introduced into the manufacture of iron which created more surprise in the minds of practical smelters and of scientific men than Neilson's discovery of the hot blast.

In 1829, Messrs. Dunlop & Co. consumed at the Clyde Works, near Glasgow, nearly 7¾ tons of coal to make a ton of pig iron, of which about 20 cwts. was employed under the boilers of the blowing engines, leaving nearly 7 tons for the consumption of the furnace itself. In the year 1833, by heating the air to 612° F. (322° C.), they reduced the 7¾ tons to 3 tons by the mere burning of 8 cwts. of coal in the apparatus for raising the blast to this temperature. The statement just given is strictly true in a commercial sense, but when we come to consider the question as one of physical science, it is necessary to eliminate some of the conditions which conduced to so extraordinary a result.

Anterior to Neilson's time the fuel employed in smelting iron was coke, and it was supposed at that period, erroneously, however, that coal in its raw state, when burned with cold air, was totally unfit for the purpose in question. This mineral, as it was obtained from the Lanarkshire coal-field, contained about 35 per cent. of volatile matter, but the process of charring it was performed in so unskilful a manner that instead of receiving 88 cwts. of coke from 135 cwts. of coal, 60 cwts. only was the product of the operation. Again, the reduced consumption of carbon in the furnace itself was accompanied by a corresponding diminution of blast, and this was followed by an economy of half a ton in engine coal. After making a proper allowance, however, for all these collateral circumstances, we are within the mark when we admit that in actual coke, which is really the form the fuel has to assume before it is burnt in the blast-furnace, not less than 30 cwts. was saved by heating the blast to 615° F. (322° C.). This unexpected economy, be it remembered, was obtained by the combustion of the 8 cwts. of coal, somewhat wastefully applied in the hot-air apparatus.

Numerous have been the opinions advanced by different authorities in the scientific world to account for the apparent anomaly, but none,

in my humble judgment, satisfactorily explains the mode of action of the hot blast. The object of this communication, therefore, is to present for your examination certain views which I have been led to adopt on this subject, after bestowing upon it some considerable attention.

Before proceeding to do this, I would ask you to review very briefly the nature of the process which is carried on in an iron furnace, whether it be fed with hot or with cold air.

In opposition to opinions formerly expressed by others, I ascertained, during an extensive series of experiments, that oxide of iron was susceptible of reduction to the metallic state at temperatures far below that believed to be necessary. This was proved in a variety of ways. Oxide of iron obtained artificially, and as it exists in various ores, was exposed at known temperatures in the laboratory to currents of carbonic oxide as well as to mixtures of this gas with different proportions of carbonic acid, the latter substance, as is well known, being the product of the reduction. Secondly, the same substances were afterwards placed in cavities in the blast-furnace, so as to secure, as nearly as possible, a treatment analogous to that which they undergo in the actual process of smelting. Thirdly, the gases of different furnaces, taken at different heights above the tuyeres, were analyzed, by which means it was ascertained that, when the combined oxygen they contained approached in quantity to that corresponding with the nitrogen as it is found in atmospheric air, the materials under treatment had, at certain points, ceased to give off any notable quantity of oxygen gas.

In a very few minutes, therefore, after the ore is shot into the throat, reduction begins, and in most cases by the time it has travelled downward through 12 or 15 feet this division of the process may be said to be completed. Below this level, omitting any chemical action connected with the formation of cyanogen salts, the value of height in a blast-furnace must only be regarded as a means of intercepting the heat which is carried upward by the rapid current of gases generated by the combustion of the fuel at the tuyeres. These gases, immensely expanded by the high temperature prevailing in the hearth, arrive speedily at the point of exit, and in the event of the furnace being of insufficient height, they carry with them, in the form of sensible heat, the useful effect of a considerable portion of the combustible employed in the operation.

This, however, is not the sum of the loss due to inadequate dimensions. Each equivalent of peroxide of iron (Fe_2O_3)—the usual

compound of the metal as it exists in our ores—requires for its reduction three equivalents of carbon which may be presented either in its solid form or as gaseous carbonic oxide. In the former case carbonic oxide, and in the latter carbonic acid, is the product of the reaction. In most cases it is the lower oxide of carbon which is the immediate agent of reduction, but in the event of this operation taking place where the contents of the furnace are at a very high temperature, the carbonic acid so formed is brought back to the state of carbonic oxide, by meeting with highly incandescent carbon. In this way, to all intents, the heat evolved does not exceed that obtained by burning carbon direct to the condition of the last-named gas.

In addition to the source of carbonic acid just mentioned, there is a second one arising from the dissociation of carbonic oxide, two equivalents of which are split up by oxide of iron into one equivalent of carbon and one of carbonic acid. It is equally important that this action should also be effected where the temperature does not suffice to reduce it to the state of carbonic oxide, in the manner already described.

By means of suitable openings in the sides of two furnaces, one of 48 and the other of 80 feet in height, I learned that in the smaller one, by the time the materials had reached the depth of 12 feet from the top, they had attained a full red heat, whereas in the larger its contents did not acquire this temperature until they had descended to a distance of about 24 feet from the charging plates.

Repeated analyses of the gases as they left the furnace satisfied me that nearly the full equivalent of carbonic acid due to reduction, and to carbonic oxide dissociation, was to be found in those of the loftier furnace, whereas something like one-fifth of this higher oxide of carbon had disappeared in the other. When it is borne in mind that the heat generated by a unit of carbon burnt to carbonic acid, and of one burnt to carbonic oxide is as 3.33 to 1, the great importance of avoiding using carbon directly in its solid form as the reducing agent, or of partially unburning the carbonic acid, will at once be appreciated.

Until a dozen years ago the furnaces in general use rarely exceeded 50 feet in height; indeed, having regard to the imperceptible character of the advantage which ensued from any moderate addition to their capacity, it is not extraordinary that those ironmasters who added a yard or two only to the dimensions of their furnaces should not have pursued any further alteration in the direction referred to.

About the period just spoken of, an experiment of a much bolder nature was tried by Messrs. Bolckow & Vaughan, at Middlesbrough, who raised one of theirs from 45 to 75 feet, retaining the original diameter of 15 or 16 feet in the boshes. Immediately afterward, still larger dimensions were adopted, and, in process of time, the example of the North of England extended to some cold-blast furnaces in Shropshire. The change was eminently satisfactory, for the saving in fuel proved almost exactly the same as had been formerly accomplished by the substitution of hot for cold air in furnaces originally engaged in smelting the minerals in that locality.

Now, had the use of furnaces, 70 or 80 feet high, preceded Neilson's invention, I do not think that it would have occurred to us to have attributed the saving of coke to any mysterious peculiarity in the nature of the combustion which takes place at the tuyeres. Instead of propounding puzzling doctrines, as has been done, to account for the heat proceeding from a few hundredweights of coal burnt in the hot-air apparatus, saving a much larger weight in the furnace, we would probably have sought to identify the mode of action of the hot-blast furnace with that of a mere addition to its capacity.

I propose to show, in the first instance, how the substitution of heated for cold air is equivalent to an increase in the capacity of a furnace, and then to follow this up by pointing out other circumstances which, in my judgment, perform a supplementary part in raising the efficiency of a furnace using hot blast. Before attempting this, I would remark that in all cases the fuel employed in the smelting process must be considered as coke, the iron produced may be regarded as that known as No. 3, whilst the air was invariably heated by the waste gases collected by hermetically closing the furnace by means of the arrangement known as the cup and cone. From repeated analyses of the gases from a 48-feet hot-blast furnace, and by careful examination of the temperature of the air it received, I was led to conclude that out of every 100 heat units evolved in its interior, there was due to combustion of carbon, 86 units, and contributed by the blast, 14 units.

So far then as an abstract question of volume of gas is concerned, 14 per cent., in the instance just quoted, is produced without any more vaporous matter escaping from the tunnel head than if 86 units of heat had resulted from the combustion of carbon fed with air at 0° C. (32° F.). If, however, we propose to ourselves the problem, as to the increase of capacity required, to permit the flow

of gases through the contents of a furnace to correspond with the diminution of volume due to the heat contributed by the blast, 7000 cubic feet in one blown with cold air ought to be equal to the duty performed in 6000 cubic feet worked with hot blast. This is too small a margin to bring the consumption of coke per ton of iron to the same figure in each case; moreover, as furnaces receiving air at a high temperature afford a much larger produce of the two, the economy of fuel cannot be said to accompany, in a ratable manner, the increase of useful capacity, when such increase is the consequence of the diminution of the volume of gaseous matter passing through them.

If from any cause the relative proportions of coke, ore, and limestone are changed, the power of the mixture to interrupt and return to the hearth the ascending heat of the gases is also modified at the same time. Experimentally it was shown that the materials used on the banks of the river Tees, possessed bulk for bulk the following cooling properties on gases passing through them at a temperature a little above that of melting zinc.

Coke, taken as unity,	1.00
Limestone,	1.60
Calcined Cleveland ironstone,	2 00

From these figures it was estimated that the ordinary burden of a hot-blast furnace possesses a heat-absorbing power about one-tenth superior to that of one blown with cold air, and by so much at least is the useful capacity of the former raised by the change. We have then rushing upwards through the contents of the furnace an immense volume of highly heated gas meeting a descending column of solid cooler material. In cases where these two currents are moving more slowly than in others it might be imagined *a priori* that the gases would part with more of their heat, and, as a natural consequence, that the consumption of fuel would be lessened. The very reverse, however, is the fact, unless the rate of driving is in excess of the power of the structure. Circumstances arose at the Clarence Works which rendered it necessary for some weeks to slacken the quantity of blast received by six furnaces having a height of 48 feet and a capacity of 6000 cubic feet. The following shows the effect of the alteration:

Average make per week.	Average number of iron.	Cwts. coke.
Tons, 246 (normal speed of work).	3 73	27.50
" 219	3.45	28 98
" 206	3.20	31.06
" 186	3.60	30 34

Within certain limits, therefore, the gases rise in temperature under such conditions as those just described. The heat carried out of the furnace represents so much loss, and, more or less, the effect of the change manifests itself in the figures by an increase in the quantity of combustible required for the same duty.

The phenomenon just described I conceive to be due to the generation of heat which takes place in the reducing zone of the furnace, which, in one of 48 feet in height, is confined to a third or fourth of its upper part. Of the 86 units already referred to as evolved by the combustion of the fuel, fully one-third is due to the conversion of carbonic oxide to carbonic acid, which conversion is exclusively effected by the oxide of iron of the ore. It is true the escaping gases do not, by their temperature, indicate that so large a proportion of the heat developed by the combustion of the fuel is produced so near their point of exit. The absence of a corresponding amount of sensible heat in the gases is due to its absorption by the oxygen in the change of this substance from the solid to the gaseous form. The balance between these opposing tendencies is not considerable, and it being a doubtful, and at the same time an important matter, in a practical point of view, I made its investigation the subject of direct experiment on a large scale. The temperature of the gases escaping from a furnace was observed during a sufficiently long time to obtain a pretty close approximation to a correct average. The iron ore was then withdrawn and an equal weight of a mixture of blast furnace slag and flints was charged in its stead. During the use of these substances, inert so far as any chemical action between them and carbonic oxide is concerned, the average temperature of the gases fell about 100° C. (180° F.).

It will be shown hereafter that the circumstance of the upper region being a heat-evolving one, is of importance, because to it, in my opinion, is due the fact that after certain dimensions of furnaces are reached, no further cooling of the escaping gases ensues from their having to pass through an increased quantity of the solid material used in the process. Seeing that the mere cooling of the gases, due either to the size of the furnace or to a diminution of their volume, as happens where heated air is employed, does not suffice to account for all the economy effected by pursuing either of these modes of working, we are led to consider whether the chemical conditions attending the process are not modified by the change, and modified in the same way in both cases, *i. e.*, when we raise the temperature of the blast, or increase the capacity of the furnace. The

only phenomena of a purely chemical nature necessary to be considered for our present purpose, are the reduction of the iron to its metallic state and the behavior of the carbonic acid which accompanies this process.

The deoxidation of an ore of iron is of course a work of time, for the reducing gas has to penetrate into masses of greater or less magnitude. If, before it has done this in a perfect manner, the mineral reaches a zone of the furnace where the temperature enables the carbon of the fuel to attack the carbonic acid generated by the act of reduction, we have to submit to the loss already referred to. Should this reversed action take place, to the extent of one-half the carbonic acid due to the operation, a loss of about 20 per cent. of the heat required for the smelting of a ton of pig iron ensues.

The advantage, therefore, resulting from the use of a sufficiently lofty furnace is the adjustment of the temperature of its different zones, so that the ore is reduced under circumstances where, so far as possible, this unburning, as it were, of carbonic acid is avoided.

The same end is attained by diminishing the volume of gases attending the generation of a given amount of heat. This happens when the blast itself is raised in temperature, while the saving of furnace fuel is necessarily increased by the heat of which the air is thus made the vehicle.

Before proceeding with proofs in support of the general correctness of the views just set forth, I would shortly direct attention to what has been assigned by other writers as the cause of a saving of fuel which could not of course be accounted for by the actual heat contained in the hot blast itself.

Practically, they all amounted to the same thing—an increased temperature in the zones of combustion and fusion, resulting from a more rapid burning of the fuel, or by avoiding the refrigerating effect of throwing a large body of cold air into the hottest part of the furnace. I may observe, in reference to this supposed change in the velocity with which the atmospheric oxygen combined with the carbon at the tuyeres, that, so far as I know, no analyses of the products of combustion have been adduced in justification of such a hypothesis.

The experience afforded by the Siemens regenerative furnace might appear to warrant the conclusion of an increased intensity of temperature by the preliminary heating of the blast. There is, however, no real analogy between heating the air for smelting iron and that required by Siemens, because in every cold-blast furnace the

so-called "regenerative" principle is already in constant operation. The materials above the tuyeres in it, as they descend in a continuous stream, perform precisely the same office as that obtained from the brick cells of the regenerator. I have sought, upon different occasions, to learn to what extent the incoming solid contents of a blast-furnace acted in the manner just described. Immediately on blowing in, the temperature of the escaping gases was taken, and observations on this point were continued until their mean heat became stationary. By estimating the total quantity produced by the coke, during the period in question, and deducting from it the heat known to be absorbed by the performed duty, the difference was regarded as that retained by the materials. From the data thus procured it was estimated that, during any given time, of the heat actually available in the hearth, 70 per cent. was due to that previously generated and returned to the region of fusion by the current of solids during its descent.

Attending the supposed more rapid combustion at the tuyeres was an elevation of temperature which, in some unexplained way, had to operate beneficially in effecting the fusion of the pig iron. It appears to have been overlooked that the addition of more material, to be acted on by a given weight of coke, would tend to reduce the heat of the hearth of a hot-blast furnace to that of one blown with cold air. I maintain, however, that the grade of metal produced is of itself an unmistakable indication of the temperature at which the iron was melted, and which, from its intensity, it is difficult otherwise to measure. As is well known, the higher grades of pig iron require during their manufacture a more intense heat than the lower; I was therefore led to conclude that if the lowest quality, *i. e.*, white iron, were exposed to a temperature sufficiently elevated to produce gray metal, a corresponding alteration in its quality would follow. A bar of white pig was in consequence plunged into the current of cinder flowing from a furnace making No. 3 iron, the effect of which was to fuse the iron at a temperature closely resembling that required for the production of gray metal. After flowing down the runner, so as to bring the melted metal as nearly as possible to the same heat as the cinder, it was intercepted in a cavity scooped out in the channel for the purpose. The iron thus treated resembled almost exactly in quality that being smelted by the furnace where the experiment was tried. In the matter of mere temperature, therefore, I think we may assume the quality of the pig as

a fair index of the temperature of the hearth of any furnace whether it be blown with hot or with cold air.

It was moreover early remarked by manufacturers and others that the economy in fuel effected by the use of hot air varied considerably with different ores smelted by its aid. With Scotch black-band the saving was not less than 30 cwts. of coke per ton of iron manufactured, whereas in Wales it did not much exceed one-third of this quantity, and again in France furnaces were instanced where the change in quantity of combustible used, after heating the blast, was scarcely appreciable. Now, it is difficult to understand if the readier fusion of iron in a hot-blast furnace was productive of the great measure of economy in Scotland, why it should be almost entirely inoperative in France.

It has been my wish to explain that the establishment of a certain position of equilibrium in the furnace is productive of economy, because by it the reduction of the ore and consequent generation of carbonic acid is confined more or less to a zone where the heat does not permit this gas to be affected by the presence of carbon. If this be conceded, then it is clear that if one ore parts with its oxygen more readily than another, a furnace working the less refractory might have its desired position of equilibrium materially disturbed by the substitution of one requiring a much longer time for its reduction.

That different ores of iron do differ in susceptibility to reduction is conclusively established in actual practice as well as by the following experiment, in which the specimens were simultaneously exposed to a current of carbonic oxide, at a temperature of 410° C. (770° F.) during a period of six hours:

Unroasted specular ore of Elba lost of its oxygen, . .	18 1 per cent.
A specimen of roasted spathose ore, ...	41 9 "
A specimen of roasted Cleveland stone, ...	50.6 "
A specimen of unroasted Lancashire hematite, . . .	70 9 "

These figures point irresistibly to the conclusion that a furnace just large enough for working satisfactorily with Lancashire ore would have its conditions materially affected for the worse by giving it the more refractory ironstone of North Yorkshire to smelt. We shall see hereafter that the red hematite can be advantageously smelted in a smaller furnace than happens with the oolitic stone of Cleveland.

It must also be kept in view that as reduction proceeds very slowly

at low temperatures it is essential that sufficient time should be afforded for this operation, before the ore reaches a depth in the furnace where carbon is dissolved by carbonic acid. The figures below show how rapidly reduction is impeded by a lowering of the temperature at which it is carried on, Cleveland calcined stone being in all cases the ore employed.

Temperature.	Loss per hour of original oxygen
Bright red,	18.94 per cent.
Red,	7 87 "
445° C (779° F),	5 80 "
260-270° C. (500-530° F.),	1 31 "
221-238° C. (430-460° F),	0 28 "

In the first constructed hot-blast furnaces the evils already referred to were mitigated but not entirely removed. The gases by their escape at a high temperature and the reduction of carbonic acid back to the state of carbonic oxide were still the source of a considerable waste of fuel. The blast itself, from some prejudice in the minds of furnace managers, was also rarely if ever heated beyond the point where it was just able to melt lead.

About twenty years ago the Cleveland ironmasters in the North of England raised the temperature of their blast to about 485° C. (905° F.) with considerable advantage in the matter of coke, and ten years later the large dimensions of Messrs. Bolckow & Vaughan's furnace were added to considerably by other manufacturers, two at the Clarence Works being 80 feet high, with boshes of 20 feet and a capacity of nearly 16,000 cubic feet. The saving in fuel from these two alterations may be approximately stated at 8 or 9 cwt., of which two-thirds was due to the enlargement of size.

These highly satisfactory results inspired some makers with what at the time I regarded as rather extravagant ideas of what might be accomplished in the directions just named. One set of gentlemen was found recommending the use of blast heated to a couple of thousand degrees of Fahrenheit, another urged the adoption of furnaces containing 70,000 or 80,000 cubic feet, while a third did not hesitate to advocate the expediency of uniting this intense temperature in the heating stoves with enormous dimensions in the furnace, by which it was expected a ton of iron might be smelted from Cleveland ironstone with 13 or 14 cwt. of coke.

The substitution of fire-brick for iron in the hot-air apparatus tended to encourage these hopes, inasmuch as the comparative inde-

structibility of the material employed, offered, it was considered, no hindrance to obtaining the blast even beyond the temperature already named. Furnaces at the same time were erected having in one case a height of 103 feet and a capacity of 33,000 feet, and in another 90 feet with boshes of 35 feet without any approach to the realization of expectations counted upon seven or eight years ago.

It has been stated upon different occasions by advocates of the use of intensely heated air that we are justified in assigning to every addition of 100° to the blast the same saving as that effected by any other 100° which preceded it. This is manifestly an error, because, with each step in the diminution of the fuel consumed, there is a corresponding diminution in the quantity of air required, so that to carry the same amount of heat into the furnace, represented by the 100°, the last must be raised progressively to a much higher point as the quantity of fuel and air are reduced in weight.

As an example, suppose the case of a furnace working with 22 cwts. of coke to the ton of its produce, by raising the blast 96° C. (173° F.) we might, so far as a question of heat is concerned, reduce this coke by one cwt., but to reduce the coke from 16 cwts. to 15 cwts., the blast would have to receive an addition of 201° C. (362 F.) to its temperature. The consequence of this is, that to command the quantity of heat considered necessary for smelting a ton of iron in Cleveland, the air would have to be delivered into the furnace at a temperature something like 1300° to 1400° C. (2372° to 2552° F.) to enable us to obtain it with 15 cwts. of coke.

Notwithstanding the durable nature of the fire-brick stove, it is questionable whether, unless with an enormous plant, blast of this temperature could be supplied with regularity and constantly, owing to the slowness, compared with iron, with which this material communicates its heat to a current of air. I am not aware whether the impracticability of conferring such temperature as that just named upon the blast, or what the circumstances are, which have led to the abandonment of the hope of obtaining a ton of iron with three-quarters of a ton of coke or less, but 18 cwt. or thereabouts is still confidently predicted as being the future consumption of fuel, in the North of England, by one or two gentlemen.

In confirmation of this doctrine, limited periods of working have been given, showing what I regard as an exceptionally favorable state of things. It is unnecessary, however, in the presence of practical men, to dwell on the unsatisfactory character of the results of a single week, where there are so many disturbing elements familiar

to any one with any knowledge of a blast furnace. That which can be done for one week ought to be capable of indefinite repetition, and until this is accomplished I prefer seeking for an explanation of those causes which appear to me to present a barrier in reducing the weight of fuel required in the blast furnaces of the North of England.

From what has preceded, economy in this respect has to be achieved, it is pretended, by extraordinary dimensions of the furnace, and by a substitution of heat conveyed into its hearth by the blast, for that evolved by the coke or other fuel. I propose examining these two branches separately. In order to effect any saving by an addition to the capacity of the furnace, we must dismiss as untenable the idea already propounded of there being any actual evolution of heat in the zone of reduction, because by it there must prevail a constancy of temperature from the reasons already explained in connection with this part of the process, to whatever height the furnace is carried. We shall, therefore, regard the temperature of the escaping gases as one determined, not by chemical action, but by a current of heated vapors, meeting another of solid cool matter, and view the question as one ascertained by actual experience and observation. The cooling power of the solid matter on the gases ought, in such a case as that supposed, to be influenced by the time in which the two classes of substances remain in contact with each other. The following sets of figures, exhibiting the quantities of solid and gaseous substances passing through furnaces of four different sizes, will give an idea of the opportunity afforded by each to intercept the heat contained in the gases, and so returning it for useful purposes to the hearth.

	Cwts. of materials descending and cubic meters of gas (0° C. and 760 mm. = 32 F. and 30 in. Bar.) ascending per minute.		These quantities compared with each 1000 cubic feet space per minute.	
Dimensions of furnace. Cubic Feet.	Cwt of materials.	Cubic meters of gas.	Cwt. of materials.	Cubic meters of gas.
48 × 16 = 6,000	1.863	138	.310	23
80 × 19 = 12,000	1 973	132	.164	11
80 × 20 = 16,000	2 654	178	.166	11.1
80 × 25 = 26,000	3.033	203	.116	7 8

The mean temperature of the gases leaving the furnace of 6000 cubic feet, may be taken at 450° C. (842° F.), whereas from that of 12,000 cubic feet they were about 120° C. (216° F.) below this. We would be quite prepared for learning that although the furnace stand-

ing third in the list is 33 per cent. larger than its immediate predecessor, its gases should, nevertheless, escape at the same temperature, because the ratable work performed is almost precisely the same in each case. When, however, we come to the last one, with a capacity of 26,000 cubic feet, and only doing 70 per cent. of the duty of the previous two, and are informed that no further cooling at the escape-pipe is accomplished, we are constrained to admit that furnaces of 12,000 cubic feet have done all that can be effected in the direction in question. I may add that, since these calculations were made, other furnaces, having a cubic content of 22,500 feet, have been set to work with precisely the same results, and when it is stated that the observations upon which the estimates are based extend over several years upon no less than eighteen furnaces, it must be allowed ample opportunity has been enjoyed to test their correctness.

It may be observed before leaving this subject that, on the assumption of the gases being cooled by simple heat-abstraction, as has been claimed from 330° C. (626° F.) to about 165° C. (329° F.), the heat thus intercepted is represented by about 1 cwt. of coke, burnt or oxidized, as happens in a blast furnace in the Middlesbrough district. This, therefore, would be the amount of economy capable of being realized by such a change, were it possible. Of course such an extent of cooling as that named is quite conceivable, if the materials charged contained an unusual quantity of water, but my remarks contemplate the existence of no such cause of disturbance. Whether the constancy of temperature in the vaporized substances which leave our furnaces, after certain capacities are obtained, be regulated by reactions of a chemical nature in their upper regions or not, we must look, I would submit, to the science of chemistry if we wish for further enlightenment before introducing changes in a plant involving the outlay of enormous sums of money.

In directing attention to an examination of the natural laws which govern the action of an agent like carbonic oxide or an iron ore, I will be as brief and as free from scientific detail as possible.

In the course of experiments, already referred to, it was proved that the roasted ironstone of the Cleveland hills manifested signs of reduction when exposed to a current of pure carbonic oxide, at a temperature of about 200° C. (392° F.), and it has already been stated in the course of these remarks that deoxidation was rapidly promoted by each succeeding elevation of temperature. We have already seen how the existence of an excessive quantity of carbonic acid, the gaseous product of the reduction of oxide of iron, operates

on the fuel in the smelting furnace; but, irrespective of this, the reducing power of carbonic oxide has a limit, that is, it cannot go on indefinitely depriving an ore of iron of all its combined oxygen. As an illustration of this limited power, let us imagine a quantity of oxide of iron raised to a full red heat and in that condition to have a stream of gas in which one-half of the volume of carbonic oxide has already been converted into carbonic acid. Reduction would go on until the peroxide of the ore lost one-third of its oxygen and was brought to a state of protoxide, when further action ceases.

Again, instead of an ore of iron, let a specimen be taken in which the iron had been perfectly reduced to its metallic condition. On treating this precisely as was the oxide, we will find it robs the carbonic acid of the mixed gases of oxygen, and this continues until the iron has become converted into protoxide. Equal volumes, therefore, of carbonic oxide and carbonic acid and protoxide of iron at a full red heat present an example of static equilibrium which is incapable of disturbance.

To enable metallic iron to split up or decompose carbonic acid, a higher temperature is necessary than that at which carbonic oxide is enabled to reduce the ore. Two hundred degrees C. (392° F.) has been cited as that required for the last-named reaction in the case of Cleveland ironstone, but to enable carbonic acid to reoxidize the reduced metal, a temperature of 400° C. (752° F.) is necessary. We thus perceive that while the heat prevailing in the upper region of a furnace suffices for reduction, it is incapable of producing reoxidation.

There are thus in a blast furnace two antagonistic forces at work, carbonic oxide tending to reduce the ore, and the resulting carbonic acid tending to reoxidize the newly formed metal, or, what is the same thing, preventing its formation. The annexed table shows how these forces hold each other in check at different temperatures, when passed over metallic iron in its spongy form:

	Temperature.	Oxidation of iron.
100 vols. CO, with 100 vols CO_2, . .	417° C. (782° F.).	nil.
" " " 150 " .	Low red heat.	Not ascertained Composition of gases permanent.
" " " 47 " . .	Full red heat.	½ of that in peroxide of iron.
" " " 11 " . .	Approaching whiteness.	⅛ " " " "

Notwithstanding what has preceded, it must not be inferred that peroxide of iron is incapable of completely converting carbonic oxide into carbonic acid, but then the iron oxide must be in large excess,

in other words, this gas is only capable of removing a very small portion of the oxygen in the ore. As a natural consequence to this state of things we might expect each successive portion of oxygen which is removed from an ore to leave its associated iron with increased slowness. Accordingly I found that the loss of the gas at the lower temperature was in the first double what it was in the ninth hour of the exposure of the ore.

The facts and figures just quoted prove, firstly, that temperature promotes the reducing power of carbonic oxide; secondly, that carbonic acid retards it; thirdly, that the points of neutral action vary with the temperature.

With the information afforded by these three modifications of the action of a mixture of carbonic oxide and carbonic acid on an ore of iron at different degrees of heat, nothing can be more apparent than that we ought to be able to determine experimentally whether the gases as they leave a blast furnace, from their composition and temperature, have had their powers of reduction exhausted. All that is required is to immerse ironstone in the orifice which leads the gases away and see whether it suffers any deoxidation. Accordingly, calcined Cleveland stone was so placed in the gases immediately as they issued from a furnace 48 feet in height and containing 6000 cubic feet. In these gases 20 volumes of carbonic acid were associated with 100 volumes of carbonic oxide, the average temperature being about 450° C. (842° F.). In twelve hours 55 per cent. of the original oxygen was removed, proving that the deoxidizing agent in this case was escaping long before its powers of reduction were neutralized. When, however, a similar experiment was tried in a furnace of 15,000 cubic feet, 24 hours' exposure of the ironstone only removed 4 per cent. of its oxygen. In this case each 100 volumes of carbonic oxide were accompanied by 40 to 45 volumes of carbonic acid, and their mean temperature was about 300° C. (572° F.). There was no notable difference between the action of this furnace and one of 12,500 cubic feet, while one of 26,000 cubic feet failed to do more than had been achieved by that containing 15,000 cubic feet.

From the observations recorded in respect to the stationary temperature of the gases and their inability, on leaving an 80-feet furnace of 15,000 cubic feet, to act chemically on Cleveland ironstone, it seems to me we may conclude that a position of equilibrium has been reached which indicates the inexpediency of attempting to obtain a greater amount of useful effect by a mere increase of size.

From a variety of causes it rarely happens that a blast furnace works up to what we will assume to be its theoretical maximum of effect. I do not remember that upon any occasion I found the proportions of carbonic acid and carbonic oxide to exceed 45 volumes of the former to 100 of the latter. There are, however, reasons which a chemist will understand why the two states of combination in which carbon is found in the gases may probably be those of a simple relation to each other. Now, something like 48 volumes of carbonic acid to 100 of the lower oxide gives one equivalent of carbon as carbonic acid to two as carbonic oxide.

If this assumption be the correct one we can estimate a minimum of carbon required in smelting such an ore as that employed during my researches. In this calculation a ton of pig iron is regarded as containing 18.6 cwts. of iron, and .60 cwt. of carbon, and supposing this carbon to be derived from dissociated carbonic oxide,

	Cwts.
Each ton of metal will give of carbon, in the form of carbonic acid gas,	6.58
To maintain the equilibrium supposed, in which, in the form of carbonic oxide, there must be double the quantity of carbon, we have . . .	13.16
To which must be added the carbon dissolved in the pig iron, . . .	.60
	20.34
Of the carbon found in the gases the limestone used contributed . .	1.32
Leaving the fuel to supply the remainder, ...	19.02

To obtain the equivalent of this carbon in coke we must make a proper allowance for impurity, which in the best of the South Durham coal-fields is occasionally as low as 5 per cent., thus bringing about a ton of coke to a ton of pig. I have heard of iron in my own neighborhood being produced with as low a consumption as that just named. This certainly does not accord with my own experience, by 2½ to 5 per cent., even with the best materials, and everything in a state of favorable working. Each unit of iron obtained from the ironstone of the Cleveland hills may be regarded as necessitating the expenditure of 4250 heat units, which with 450 units usually carried away in the gases gives 4700 as the total requirement. Now a trifle above 22 cwts. of such coke as is in common use does not usually afford above 4100 heat units, thus leaving a deficiency of 600 units, which is furnished by and is that really contained in the heated blast.

I have at an earlier period endeavored to show that the efficacy of

the hot blast did not depend upon any change in the intensity of the heat or nature of combustion in the hearth, but that it operated in a twofold capacity. It contributed so much heat to the general fund, and it virtually increased the beneficial capacity of the furnace. When, however, the latter is ample in size, affording the gases sufficient time to accomplish their work with a minimum of loss, then the heat of the blast does its ratable share of the work and no more.

It may not be devoid of interest to consider shortly what ought to be the consumption of coke in an 80-feet furnace of say 15,000 cubic feet, blown with cold air, adopting as a standard of comparison the performance of a similar furnace, receiving its blast at 485° C. (905° F.). Assuming the coke to be oxidized to the same extent in both cases, it is clear we must supply the heat furnished by the hot blast by heat, to be obtained by burning an additional quantity of fuel in the furnace itself. This addition, however, will be burned only to the state of carbonic oxide, the ore having furnished all the oxygen capable of raising this gas to the condition of carbonic acid. Making proper allowance for ash, and for the greater amount of heat which will be carried away in a larger volume of escaping gases, it will be found that about 6 cwts. of coke, per ton of iron, would be needed to make up the deficit. Hence a furnace using 22 cwts. per ton, with a blast heated to 485° C. (905° F.), would consume about 28 cwts. when the air is employed at atmospheric temperature, a rate of consumption which accords with actual experience. This affords an additional proof, if such be necessary, that heat contained in the blast differs in its action in no way from that evolved by the coke.

Before leaving the subject of the oxidation of the furnace gases, it must be remembered that the preceding remarks are applicable only to a furnace kept regularly filled. If this be neglected, a loss of fuel may be the result, notwithstanding that the carbonic acid increases largely in quantity. The effect of this is manifested in a rise of sensible heat in the gases themselves, which accounts at once for the prejudicial effect, well known to furnace managers, on work performed under such circumstances. If, then, as experience has demonstrated, no benefit in the matter of coke has been derived from increasing the size of our furnaces in Cleveland beyond a height of 80 feet, with a capacity say of 15,000 cubic feet, let us consider whether any advantages, in respect to the weight of production, have accompanied the more recent additions of size. This question has been indirectly alluded to when speaking of the relative quantity of

solids and gases passing through furnaces of different dimensions, but for our present purpose I will quote the actual make of iron from furnaces of the four dimensions already quoted.

Height of furnace, and size of bosh, .	48 x 16	80 x 19	80 x 20	80 x 25
Cubic contents, feet, ...	6000	12,000	16,000	26,000
Average of weekly make, for 1000 feet of capacity, tons, ...	36.6	23.7	21.8	15.3

These figures show that a furnace of the largest size given does not perform within 30 per cent. of the ratable work compared with one of 16,000 cubic feet. I would remark that, having abundant blowing power, as well as the means of heating an extraordinary supply of blast to some of the furnaces at the Clarence Works, attempts from time to time have been made to bring up the ratable make of the larger furnaces to that of the smaller of those having in both cases a height of 80 feet. These attempts have always failed, because they were invariably accompanied by a notable increase in the consumption of fuel, arising partly from mechanical difficulties in the management of the furnace, on which want of time here will not permit me to dwell. Let me say, however, in reference to this question of dimensions, that I am not prepared to advise any serious reduction from the largest furnace mentioned in this communication, because there are matters connected with manual labor, which, from a commercial point of view, lead me to prefer furnaces of a capacity beyond that where efficiency in other respects has ceased to advance.

In the event of my having been fortunate enough to make myself perfectly understood in describing the chemical reactions which take place during the smelting of iron, and the manner in which they are affected by temperature, little need be said, if the opinions expressed thereon be correct, on the inutility of raising the heat of the blast beyond a certain point. This belief is based on the idea that a certain proportion of carbon oxidation cannot be exceeded, and that as soon as the heat contained suffices to make up the total sum required after the fuel has been oxidized or burnt to the maximum state permitted by the nature of the process, further elevation of temperature in the blast is useless.

To those who have never studied the action of the blast furnace as a question of abstract chemistry, it may appear incredible that a quantity of heat represented by the difference of blowing in air at 480° C. (896° F.), and at 750° C. (1382° F.) should be unproductive

of any benefit in an operation where heat undoubtedly plays so important a rôle as it does in the smelting of iron.

This advantage has been publicly stated by one of the advocates of the use of superheated air in furnaces of the largest size to be 2 cwts. of coke for every 111° C. (200° F.) added to the temperature of the blast. It has been demonstrated, it is hoped with sufficient clearness, on physical grounds, firstly, that no such rule as that laid down is possible; and secondly, that when the furnace is sufficiently capacious the coke saved is equivalent, and no more than equivalent, to that contained in the blast. Now the difference between 480° C. and 750° represents 456° F., which, at 2 cwts. of coke per 200° F., the economy claimed, represents fully 4½ cwts. of this description of fuel, whereas the actual difference of heat in air at the one temperature and the other barely amounts to 1¼ cwt. of coke, which is a proof of the unsoundness of the statement of the saving.

Looking at the complicated nature of the changes which accompany the smelting of iron, and at the difficulty of examining with the necessary precision each step in the process, it is not surprising that some doubt should, on the question before us, still linger in the minds of some who have upheld the value of superheating the air consumed in the blast furnace. With such conflict of opinion there is no alternative but to examine with the requisite care the results of actual experience. A large quantity, as much as 2,000,000 tons, I understand, of pig is annually made with superheated air, and certainly, so far as its application to the furnaces of the North of England is concerned, there have been obtained as favorable results in furnaces of 22,500 cubic feet, with blast at about 485° C. (900° F.), as have been commanded by other manufacturers in furnaces one-half larger, and blown with air fully 200° C. (360° F.) higher than that in use in smaller furnaces.

Reference in an earlier part of this paper was made to the greater facility with which the red hematite of Lancashire suffered reduction, when compared with the ore of Cleveland, the difference being stated as 7 to 5. This hematite was treated in furnaces 55 feet high, in which a ton of pig iron was smelted with an equal weight of coke or thereabouts. When the ironmasters of the West of England learned that an advantage had followed the use of large furnaces and of superheated air on the East coast, one of their number was soon found following so encouraging an example. This costly change in the Lancashire plant has been unproductive of any benefit, for the simple reason that with an ore so susceptible of reduction as that in

use in that district, the position of static equilibrium, already explained, is secured in furnaces of smaller capacity than happens when the mines furnishing the more refractory ore of Cleveland are the source of supply. It is, however, needless to quote the experience of English ironmasters to an assemblage containing within its ranks names of great eminence in the American iron trade. In no country are there more striking instances of the different character of ores than in the United States, and every one who has studied the question is fully aware that large quantities of iron are run from individual furnaces of very moderate size. These are blown with air of no extraordinary temperature; the consumption of fuel at the same time does not exceed that in the lofty furnaces of the North of England.

This is so peculiarly the case when the iron is produced by means of charcoal, that I avail myself of the present opportunity to recommend the action of these furnaces as a subject of special study to those who have the time and opportunity to devote to this interesting subject. There are actually to be found instances in different American localities where furnaces 40–42 feet high, with boshes of 9½ feet, and, therefore, containing probably not above 1500 cubic feet, are running 250 tons of the richest gray iron in a week. This extraordinary production for such a capacity is achieved with the blast at 370° C. (700° F.), no benefit accruing from raising it to a higher temperature, and yet in some cases a ton of metal is said to be obtained for even less than an equal weight of charcoal.

The opinions just set forth on the inexpediency of heating air beyond a certain point are only applicable to furnaces where the dimensions are sufficiently large to afford the reducing gas ample time to expend its energy on the work it has to perform. Precisely in the same way as a small cold-blast furnace of 6000 cubic feet has its activity promoted by heating its air to 600° F., so a larger one, say of 8000 cubic feet, may have its blast advantageously raised from 900° to 1200° F. What I maintain is that dimensions of furnace and temperature of blast are convertible terms until we arrive at a certain composition of the gases. This composition infers so much carbon (one-third, I have assumed) burned as carbonic acid, and two-thirds as carbonic oxide, and carbon thus burned means a given quantity of heat. As the heat required for smelting iron varies in amount with different kinds of ores, so the extent to which that afforded by the combustion of the fuel has to be supplemented by the heat contained in the blast also varies. In illustration of this law

furnaces of 10,000 cubic feet in England are found doing the same work, in point of consumption of coke, as others at 15,000 feet, but in the former case the blast requires to be elevated to 700° C. (1290° F.), whereas 480° C. (896° F.) suffices in the latter. This experience of the Old World seems to be confirmed by that of the New, for we are informed very recently, through the columns of your own journal, that the furnace at Port Henry has been running 300 tons a week, burning a trifle under 23 cwts. of anthracite coal with air at 1350° to 1400° F. Almost precisely the same results are being obtained at Glendon, with its blast heated in iron stoves to a very moderate temperature, the fuel being also anthracite, and the ore treated, I believe, not less refractory than the rich produce of the Lake Champlain Mine. The furnace at Glendon, however, contains close on 12,000 cubic feet, and is almost exactly one-half larger than that at Port Henry.

A word or two of explanation before I conclude as to what is supposed to become of the additional heat received from superheated air by a furnace sufficiently large not to require its aid. We have already seen what happens when the dimensions are below that required for the economical treatment of an ore. In it the oxide of iron reaches a zone of the furnace where the high temperature enables the carbonic acid produced by reduction to dissolve carbon, without the evolution of heat. Let us imagine the case of a furnace sufficiently large to have reached the limit which on theoretical grounds I have assumed as the true one. In it let us further suppose that the blast is exactly raised to the temperature which enables it to supply the heat in deficit after the fuel has been oxidized to the extent described. If in such a case a large amount of heat is conferred upon the blast, as can be done with the fire-brick stove, the zone of high temperature commences *pro tanto* to extend itself toward the throat of the furnace, where it meets with unreduced oxide of iron. Such a mode of procedure is clearly equivalent to letting the ironstone descend to the region of high temperature before it is perfectly reduced; in both cases heat is wasted by the unburning, as I have termed it, of carbonic acid.

In closing these remarks on the theory of the hot blast and on its action, I may state that the views I have endeavored to explain to my brother ironmasters on this side of the Atlantic are founded on experimental labors and investigations having for their object the solution of a purely practical question. My firm was among the first who proposed following up the idea of my late friend, John

Vaughan, which we did by the adoption of dimensions nearly one-third larger than those he had attempted, to which was applied blast at a temperature beyond that he could at that time command. The results indicated some improvements by this change of conditions, and it therefore became absolutely necessary for our own guidance in the future to learn whether any further addition to the capacity of the furnace or to the temperature of the blast would present any advantage in the economy of fuel.

When, with the Cleveland ironstone, the furnace has reached, at the very outside, 15,000 cubic feet, and has its blast heated to 485° C. (905° F.), I answer this in the negative. If the opinions thus formed embrace any fallacy, they at least possess the recommendation of constituting those upon which I have recommended those associated with me to act. As such it affords me much pleasure in submitting them to the criticisms of my associates in the Institute of Mining Engineers of this great country; an institution which has distinguished me by adding my name to its small list of honorary members, and from which I received so many proofs of most friendly welcome upon the occasion of my former visit.

PHILADELPHIA, June 28th, 1876.

MR. F. FIRMSTONE.—I will not attempt to discuss Mr. Bell's paper, but I would like to speak of some points which may be of service in any future discussion.

I think Mr. Bell is almost certainly right on every point, but there are some difficulties. He has shown more clearly than any one else that the effect of the hot blast is in proportion to the quantity of heat carried into the furnace, and thus has shown that there is nothing mysterious in the saving of fuel effected.

With regard to the temperature of the furnace being measured by the grade of the pig iron produced, and his deduction therefrom, that the temperature of a hot-blast furnace making a given grade of iron is the same as that of a cold-blast furnace making the same grade, he is also probably right, at least it is at first sight the most rational assumption. There is one circumstance which it seems to me is a difficulty in the way, and that is the undoubted difference in

quality, for certain uses, which has often been found between the iron made with hot blast, and that made with cold blast in the same furnace and with the same ores.

I suppose it is no exaggeration to say that the charcoal furnaces in this country which have ruined their iron for chilling purposes, by changing from cold to hot blast, may be counted by the score. Although I have had but little to do with charcoal furnaces, I have seen one instance myself in which the matter received a perfectly fair trial. The iron was used by the owners of the furnace, and it was found that the cold-blast iron would give a good chill, while the same grade of hot-blast iron would not chill at all.

This matter has never been scientifically investigated, but what we do know seems to indicate that the failure to chill is due to a larger quantity of silicon in the iron, and as we know that the silicon in the pig (other things being equal) increases with the temperature in the hearth, the failure to chill would seem to point to (although it is far from proving) a higher temperature in the hearth of the furnace using hot blast.

Mr. Bell.—In reference to the difference of chilling properties in charcoal iron made with hot and cold blast, I am unable to speak from personal experience. I am ready to admit that some of the conditions of the blast furnace are so difficult of estimation, that I can readily imagine differences may arise from the use of hot instead of cold air which may materially affect the property of the metal in this particular direction.

It must be remembered, however, that I did not in my paper limit my observations to the production of any particular quality of iron; my observations, on the contrary, were of the most general kind in their application. Speaking therefore in this sense of quality, I can only refer you to the magnificent exhibit of iron in the Swedish department for a proof that the use of hot blast is not incompatible with high excellence, for in that exhibit almost all the specimens are smelted in furnaces fed with heated air. As is well known, Sweden occupies her position against the flood of cheaper iron produced in Britain by quality alone, and we may, therefore, assume that no new question of a moderate saving would have induced the Swedish ironmasters to make any sacrifice in respect to the quality of their produce.

It is true, in England, we have one or two works, such as Bowling and Low Moor, where the use of cold air is still adhered to. I have

had no opportunity, either personally or otherwise, of comparing what difference, if any, is effected by smelting the minerals in use at these works with hot air. Their produce brings a high price, and I can, therefore, well conceive that motives of commercial prudence may justify the owners in adhering to a system which is fairly profitable.

DR. WEDDING, of Berlin, after giving a comprehensive summary of the various theories which had been proposed for the action of the hot blast, said: I have followed Mr. Bell's experiments with the greatest interest, and have found that the efficacy of the hot blast is due simply to a concentration of the heat in the lower part of the furnace. A furnace working normally is in the condition of a healthy man with warm feet and a cool head. But the use of heated air has another effect, namely, in changing the quality of the pig iron produced. The only element which comes into consideration here is silicon. Manganese is reduced when it is present in the ores in sufficient amount and in favorable condition, as, for instance, as carbonate; phosphorus goes into the iron entirely under any conditions; sulphur goes off in part in the gases, and a part goes into the iron and cinder, according to circumstances. Now silicon is reduced in proportion to the temperature of the blast. This gives us an explanation, at once, why the cold-blast irons are better adapted to chilling purposes. Silicon has the property of causing the separation of carbon in the graphitic form, and chilling is an operation of the reverse character.

MR. WITHERBEE.—In comparing the results attained at the Glendon and Cedar Point furnaces, Mr. Bell speaks of the use, at the latter, of the "rich produce of the Champlain mines."

At the time of his visit, we of course showed him the best we had, that is, the richest ores, but did not show him the variety worked in the furnace, for want of time, the deposit being about one-half mile away.

The Bessemer ore used is a mechanical mixture of pure magnetic oxide and pure quartz, entirely destitute of self-fluxing qualities, and requiring some 45 per cent. of limestone. By the use of a mixture of primary limestone and dolomite, we are enabled to work the furnace very hot, which, of course, takes an extra amount of fuel. I do not now remember that Mr. Bell makes any allowance for the *mechanical* condition of the stock. The New Bed ore is coarsely crystalline and friable, so much so that we only have control of the

size of the pieces charged of about 42 per cent., while the remaining 58 per cent. falls to pieces, and is not coarser than corn, consisting of crystals of ore and quartz. In filling the stock it was found that the ore took up absolutely no room, that the coal and limestone alone would fill it.

Whenever we have used over 58 per cent. of the charge of fine ore, as mentioned above, it has produced the same effect as an over-charge, *i. e.*, scouring cinder and irregular working, although the total burden was the same.

Our flux consisted, until recently, of one-half primary limestone and one-half dolomite, giving us 5 per cent. of magnesia in the cinder. The primary limestone used was granular like the ore, and, like it, decrepitated in the furnace, so much so that it became necessary to use less of it. A dolomite was found containing only two-thirds as much magnesia as the first used, so that by using three-fourths of the new dolomite and one-fourth of the primary stone, the cinder produced was identical with the original. The result of the change was to increase the production from 5 to 7 tons per day, the furnace now producing upwards of 50 tons No. 1 and No. 2 Bessemer pig, which again illustrates the effect of a change in mechanical conditions. At the time of the Washington meeting we were carrying more burden than at present by 300 pounds of ore, besides the necessary amount of lime. The change was made on account of complaints about the quality of the iron. It is necessary to work our ores very hot to eliminate a certain element not in much demand by Bessemer steel works. That, however, is another subject which I hope to discuss at a future time.

Question.—What is the temperature of the blast?

MR. WITHERBEE.—The temperature is from 1300° to 1400° F.

Another thing I would like to state to show the utility of the Whitwell stoves in certain cases.

At 11 P.M., Saturday, May 27th, there had been put in 9 charges, which was a fair rate of running, twenty charges per shift of 12 hours being the usual number. I was sent for at 7 A.M. (28th), and told that nothing had been charged since I left (at 11 P.M. the 27th).

The founder, Mr. Cary, had already started fires under all of the boilers, and as soon as it was sure that we could maintain our steam pressure, all of the gas was turned into the stoves. At the time of my arrival both iron and cinder had refused to flow, while the tuyeres showed good coal in front of them.

Our Siemens pyrometer had been broken for some weeks, consequently the stoves had been run by guess, and the scaffold was attributed to a temporarily low blast temperature. I immediately borrowed another pyrometer of the Bay State Iron Co., and found the heat to be 1000°. During the day, May 28th, the temperature was raised to 1600°, and iron and cinder began to flow—forge cinder and mottled and white iron.

Our anxiety, coupled with the fact of an ever-increasing blast temperature, led us to increase the volume of blast, so that during the last ten hours the pressure was $13\frac{1}{2}$ pounds at 11 revolutions of the engine with 26 pounds of steam. At 11.30 P.M., the 28th, a slip occurred of 13 feet, doing no damage whatever, and the difficulty was over. The whole time the materials were stationary was $24\frac{1}{2}$ hours.

F. FIRMSTONE.—May I say one word more? It is perfectly true that some ores make excellent car-wheel iron with hot blast, but the point is that there are a great many others that will make good chilling iron with cold blast, which will not chill at all with hot blast.

If the chilling properties varies, as I suppose, with the amount of silicon, this is very natural, for we know that the amount of silicon in the pig varies with different ores when other circumstances are the same.

The comparison I alluded to was, of course, made between the same grades of iron; if, for instance, the No. 2 cold blast would chill, the No. 2 hot blast would not. The charcoal furnace men are all anxious to use hot blast, but, unfortunately, the car-wheel makers generally refuse to use the iron.

THE MINERAL WEALTH OF SOUTHWESTERN VIRGINIA.

BY C. R. BOYD, WYTHEVILLE, VA.

WITHOUT attempting to do more than give a preliminary or skeleton report upon the geology and minerals of Southwestern Virginia at this time, I am led to hope that the great commercial importance of the sixty miles of cross-section here crudely treated of

will be apparent to those who have not already rendered themselves familiar with that district.

This sixty miles length of cross-section is located directly across what may be considered, in lieu of an exact instrumental observation, the central portion of the Appalachian chain in Southwestern Virginia, having its centre near Wytheville, Wythe County, Va., on the Atlantic, Mississippi and Ohio Railroad, a main stem running from Norfolk on the seaboard toward Memphis, St. Louis, and other Western cities; a remarkably valuable parallel cross-section, which would have a centre nearly at New River Depot on the same railroad, is situated thirty-six miles further E.N.E., passing across the same geological strata as the first, with the same extraordinary mineral characteristics in the main.

The southeastern end of the cross-section is located in Carroll County, Va. (which lies just south of Wythe County), near the northwestern limit of the gneissic system; it is marked by the eruption of a six-foot vein of trap, holding particles of native copper, which occasionally, along the twenty miles length I have examined, presents interesting features, but requires a closer and much more critical inspection than I had time to give it in order to determine an approximate idea of its commercial value, my time being consumed in that vicinity by an inspection of the more interesting pyritous lode which lies but a short distance north of it. This pyritous lode is marked by extraordinary quantities of limonite, varying between 20 and 40 feet in depth by a width of from 60 to 150 feet, in many parts holding, according to Dr. F. A. Genth, about 50 per cent. of metallic iron. It was first ascertained to be the mere outcrop or iron cap of a pyritous lode holding copper by the precipitation of that metal on the iron and steel of the tools with which it was first mined for forge and foundry purposes, and finally, when a few feet depth had been reached, by showing the green crystals of the carbonate of copper. Under the iron cap, marked in its lower part by carbonate of copper, which varies in quantity from one point to another, suggesting the idea that the vein alternates in richer and poorer copper ores, there is, as usual in such veins, a bed of the black oxide of copper, accompanied by copper glance, the vertical thickness of which, observed at two points, is, respectively, two feet and three feet, giving, in its best ore, 51.53 per cent. metallic copper by Dr. Genth's analysis, and 21.08 per cent. as its poorer average. Next below are the pyrrhotite and copper pyrites, accompanied by actinolite and chlorites, and calcspar in small quantities. The copper py-

rites yield, according to the same analyst, from a strictly poor average, 1.70 per cent. of metallic copper and 9.36 per cent. from another average, leaving no doubt of the great economical value of the lode at a point on Chestnut Creek, in Carroll County, where I had the best opportunity to examine it. Here the lode has a thickness varying between 45 feet and over 100 feet, inclosed in talcose and micaceous slates and schists, traceable, to my knowledge, through the county of Grayson, Va., and Ashe, Alleghany, and Watauga Counties, in North Carolina, to the northeast into the county of Floyd, Va., and reported further on.

In the same series of rocks may be included the Ore Knob Copper Company's mine, the Peach Bottom copper mine, with its silver-bearing galenite, and the Elk Knob copper lode, of Western North Carolina, as well as the bands of magnetic and specular ores and the veins of mica, feldspar, and quartz so largely developed in that part of North Carolina. These last, copper and other veins, have been pretty fully explained by Dr. T. Sterry Hunt, Prof. Kerr, Dr. Genth, and others.*

Leaving the great copper lode of Carroll County, with its accompany steatitic rocks, some ledges of which are pure enough for furnace lining, we take up our cross-section line to the N.N.W. again, through chlorite slates and kindred rocks of the Huronian period, synchronous with the Langmynd group, having a dip S.E. and S.S.E., varying between 45° and 90° from the horizon, and traverse about five miles of a repetition of these strata to where we strike the main ridge of the Unaka or Iron Mountain range, projected northeast from Western North Carolina, Georgia, Alabama, and likely to give us those valuable measures of metallic veins by which it is characterized at other points further south, with some valuable additions in our cross-section. At this point, or near it, we might say, the New River breaks through on its way toward the Kanawha, dis-

* It will be a matter of some interest to geologists visiting that section to examine the great granite mountains in Grayson County, Va , known as Point Lookout and Buck Mountain. They have the appearance, in places, of an entire want of stratification, strongly suggesting the idea that they belong to a much older series of rocks than those around them. It may be determined that in the projection of the sides of these ancient rocks those planes of least resistance were found that resulted in the great fissures during the disturbance of the earth's crust, into which have been interjected some of the metalliferous lodes which I have attempted to describe. There is quite a similarity between this section and Cornwall, agreeably with some published accounts I have read, although they do not appear to be synchronous.

charging about 1500 cubic feet per second in usually low stages. This Unaka or Iron Mountain alone here marks the division, so far as observed, between the Huronian and Cambrian periods. In places along it, it is much disturbed, sometimes presenting the appearance of a much-disturbed anticlinal; but generally having a dip to the southeast varying between forty-five degrees and higher; having a hard conglomerate near its centre, and in its northwestern flank stratified veins of brown iron ores, the measured thickness of which at one point shows 6 feet and 9 feet for two of them, between head and foot walls of slate; which I place nearly about the junction of the Potsdam and Calciferous sub-epochs, judging from the proximity of known rocks, for no organic remains have as yet been visible to me at the point. From these veins, and others carrying manganese, immediately near, I conclude the immense beds of sedimentary ore of great purity in Wythe and Pulaski Counties are derived in part. Analyses of these ores have been so frequently made, and they have been tested practically so often by a few iron men of the section, without finding any objectionable impurities, except the ores from two or three isolated places, that I will postpone giving full analyses, and will add that the very curious may obtain valuable information as to minor constituents by referring to Messrs. Booth & Garrett, chemists, and to Prof. Fesquit, who have become very thoroughly acquainted with the iron ores of the New River region. I will say that in eight specimens taken from different points on New River, some from these mammoth beds, and submitted to these gentlemen, there was found an average of 53.68 per cent. of metallic iron, and 0.141 per cent. phosphorus; the highest phosphorus being 0.240 per cent. Four specimens of magnetic oxide gave an average of 65.062 per cent. metallic iron with 0.11 per cent. of phosphorus; two of the fragments giving no phosphorus at all. Three specimens of red hematite gave an average, by these chemists, of 65.90 per cent. of metallic iron, and 0.033 per cent. of phosphorus. It should be borne in mind that these specimens were taken from points on New River and near it, all the way from Grayson, where the river comes in from North Carolina, down to Peters Mountain in Giles County, Va., where it breaks through that mountain on its way toward Hinton on the Chesapeake and Ohio Railroad, and on to the Kanawha.

To revert to our cross-section line again: leaving the Unaka, or Iron Mountain, and going our old course, N.N.W., we fall into the southeastern border of what would be the great valley of Vir-

ginia prolonged, across which the New River cuts irregularly to the northeast, and having near it on each side much of the great sedimentary iron ore beds we have just been considering. We fall in a mile or so of the Unaka into limestones, both magnesian and non-magnesian, generally crystalline, and void of organic life; having a strike generally N.N.E., and a dip, which, for want of a better word, may be called heteroclinal, for the rocks are chopped about a great deal in places. In this series of rocks on the bank of New River we are at a forty-feet vein of lead and zinc, traceable for many miles E.N.E. and S.S.W., generally perpendicular in attitude, and just at this point owned and operated by the Wythe Lead and Zinc Mining Company, sometimes known as the Union lead mines and the Austin mines. The ores are sulphurets and carbonates of lead and zinc blende and carbonates of zinc, principally in a pure condition. This particular mine has been worked since some time previous to 1776, furnishing some of the lead used by the Continental armies, and a great part of that consumed by the Confederates east of the Mississippi in the late war, but no mining has been done below water-level. Over ten thousand tons of the zinc carbonates have been shipped North and converted into oxides, etc., since 1866. Following this great lode northeast or southwest on its course, you do not find it so well in hand as at the Wythe lead and zinc mines; at points it is thrust up in separate veins. A much closer inspection at several promising points may reveal them united to such an extent on the surface as to render mining profitable; notably, two or three points west of New River, and another near Reed Island Creek, on the lands of Graham & McGavock, where there is evidently a junction with a lode of pyrites of iron, of which I shall speak presently, and another point or two in Pulaski County, following down the course of New River in that part. The remarks above apply to the surface. There is great probability that deep mining will find many of these minor veins united into one of sufficient size to be of as great commercial value as the veins at the Wythe lead and zinc mines.

Leaving the lead and zinc vein, and crossing New River, on the line of our cross-section again, we pass over a narrow belt of lower limestone, through occasional beds of neutral brown hematite, which line this valley for miles in each direction, and strike another belt of crystalline limestone, in which there is a lode of iron pyrites, not running in one regular line through the country, but frequently broken and thrown off a regular course. At the point I could obtain the

best measure of it, it was twelve feet thick. It is decomposed almost entirely in all the hills through which it passes, leaving nearly pure limonites along through the county of Wythe on Cripple Creek, and near the New River, that I have never attempted to measure. Near this lode, just west of where the cross-section passes, are very considerable deposits of manganese oxide, which, by the tests of Prof. Cook, of New Jersey, gave 66.98 per cent. of black oxide of manganese. This ore was once analyzed specially for impurities, and no appreciable quantity was found in surface fragments. It should be tested at some depth below the surface. Near to this, to the north, is a measure of manganiferous iron ore at least four feet thick, and to the south of this there is still another vein on the north flank of the Iron or Unaka Mountain that will be soon investigated.

Leaving the iron pyrites lode and its surroundings, we pass N.N.W. again, over an interval of about two miles, on our cross-section, of limestones, red slates, etc., holding here and there brown hematites and manganiferous deposits, and arrive at the Lick Mountain—an intrusion of Potsdam sandstones, and overlying and underlying strata, synchronous with the Stiper Stones of England, in the shape of a disturbed anticlinal for a part of it, and a succession of ridges for another part—an island, as it were, in the heart of Wythe County, elevated above a limestone valley, in which, I think, may be traced such rocks as Prof. Emmons denominates Taconic. This I judge from similarity of description, and not from character of organic life, as I have found too little as yet to justify me in naming the strata on that score. In the southern escarpment of this Lick Mountain is a stratification of slaty-brown iron ore more than one hundred and fifty feet thick (I did not follow its width further), containing about 25 per cent. of metallic iron (at least in surface fragments), from which, no doubt, a great part of the iron in the ores of the valley is derived, being very elevated, and much exposed to the action of the elements. One mile further to the north in this mountain is a vein of manganese ore, apparently binoxide, crystalline in part and very dense, the thickness of which I could not obtain, as the gentleman to whom the land belongs is just now about having the necessary developments made.

Following these strata either way, you will find extraordinary surface quantities of both manganese ores and manganiferous iron ores. At one point, four miles south of the Atlantic, Mississippi and Ohio Railroad, called the Glades, in Wythe County, a shaft has been

sunk into a deposit of manganiferous iron ore of irregular measures over four feet, having cavities in which hang stalactites of manganese oxide.

To revert again: Near to our cross-section line on the Lick Mountain, and near the Potsdam sandstones that compose the heart of the mountain, is a measure of fire-brick clay, which I traced in the bed of a small stream more than 100 feet diagonally across it, not finding either wall of it; a specimen of which, with many of different ores from this region, is on exhibition with the Smithsonian Institution collection at the United States Centennial Building, as well as with the Virginia Mineral Bureau exhibit, and in a private collection of the New River Railroad Company, at T 54, Main Building.

The northern or northwestern face of Lick Mountain, immediately facing the town of Wytheville, is a repetition in great part of the southern escarpment, only that the ores do not appear on the same gigantic scale. But it has its manganiferous iron ores, red and brown iron ores, fire clay, manganese ores, and a thin stratum of slates giving traces of copper, near the northern base of the mountain. A transverse cross-section, near the Atlantic, Mississippi and Ohio Railroad, that is, in a line E.N.E. and S.S.W., will prove an interesting one to the curious. Beginning thirty miles to W.S.W. in Smyth County, there are developments of barytes, the product of the mines having been for awhile shipped North. Following the line of the railroad eastwardly from the barytes, we find flattering surface indications of specular iron ores, and further on toward our cross-section line of copper ores. But these ores have evidently been left by some glacial action, as well as those copper ores which appear in such flattering quantities on the surface near Max Meadows Depot on the Atlantic, Mississippi and Ohio Railroad, eight miles east of Wytheville. By an analysis which I had made in Baltimore, there was 9.8 per cent. of metallic copper in ore found near Max Meadows. If it should be the surface outcrop of a sulphuretted copper vein beneath, it is very close to railway transportation, leading by one road to the seaboard three hundred miles distant. Following our transverse section five miles further eastwardly into the Peak Mountain, on the Atlantic, Mississippi and Ohio Railroad, we have the outcroppings of a true anthracite coal, at the surface showing all the indications of a crushed vein, with a measure that was difficult to obtain when I was there; but it may be placed at a little less than three feet, although it appears larger. It is a subcarboniferous coal, including about here quite an area of

nearly flat dips, but presenting an appearance suggestive of faults and fissures. It should have a very strict and close survey to determine its probable value.

Going back to Wytheville, and pushing northward across the Trenton and Calciferous limestones and sandstones two miles, we come to a vein of red hematite of a magnetic character, nine feet thick, perpendicular in attitude, in limestone and flint, showing surface indications each way half a mile, at intervals. This ore has been tried by the Tredegar Iron Works of Richmond, Va. Passing on N.N.W., three and one-half miles further on our cross-section line, we go over a great fault in the crust of the earth, and suddenly find the sandstones of the subcarboniferous and slates beneath them holding eleven seams of coal, varying in thickness between three and one-half feet and a few inches. These veins have a general dip S.S.E. of about 35°, the coal containing enough bitumen to make a good coke at this point, and burning well in grates and stoves. It has never been remarked that any of this coal decrepitates in the fire. Still, as the measures have been subjected to quite different degrees of disturbance at different points, elements may have been interjected or percolated through at some points that would cause decrepitation of these coals.

Accompanying these veins above in the order of stratification is an eighteen-inch vein of black band, having on its outcrop a hydrated peroxide of iron, sometimes in hollow casts and nodes. These veins, as you go eastwardly along the southeastern escarpment of Little Walkers Mountain, in which they occur, become more of an anthracite until you reach the Peak Creek Hills, and there you find the coal an anthracite, as described above. Further eastwardly, in Pulaski County, it is nearly an anthracite in the southern face of Cloyd's Mountain. Following still further eastwardly into Montgomery County, crossing New River, the same veins are now mined very extensively for that section, having pretty regular measures from four to seven feet in thickness and less, nearly all pure coal—still with its rather high angle of inclination, S.S.E.

Going back to our cross-section line at the coal, about five miles in a straight line N.N.W. of Wytheville, leaving the great valley behind us, we strike into an alternation of lower and higher mountains. The lower mountains are composed in the central part of the Catskill sandstones, underlaid by the tolerably easily recognized gradations down to the Marcellus and Hamilton slates and shales, with those strata such as the Corniferous, Oriskany, Lower Helder-

berg either left out or but feebly represented until you reach the Niagara epoch, generally with a strike E.N.E. and dip S.S.E. 35 to 40 degrees. In going N.N.W. from the outcrop of the Catskill, on the crest of the lesser mountain, we pass across the upturned edges of the next lower stratum, descending into a valley that is composed mainly of Marcellus, Hamilton, and Genesee beds, and having a poor soil; we then begin to rise the greater mountain, passing through all or nearly all the Niagara sub-epochs until we reach the crest of the higher mountain, which is generally composed, as to its spine or centre, of the Oneida sandstone. After passing this you begin to descend very rapidly into a rich valley, passing through the Hudson shales and limestone, and generally going down into the calciferous, before that great fault occurs again which brings you face to face so suddenly with the subcarboniferous sandstone. These mountains are generally monoclinal, with the exception of one great anticlinal, of which I will speak presently. The condition above described may be the better understood by placing the two hands side by side horizontally, supposing them to hold all the strata from the calciferous up to the subcarboniferous inclusive. Point the hands toward the E.N.E. to get the direction of our mountain; imagine a wave motion to exist across many hands so placed, and press all together, sliding the right hand upon the left; you have the calciferous riding up on the subcarboniferous, with the lines between the hands representing the great faults; and if you will then consider that the elements have acted so much the more rapidly on the soft Marcellus and Hamilton shales, upturned at a high angle, you will find an explanation for the poor valleys.

This operation has been repeated across this section, or near it, four times, with the exception of a curved anticlinal in the case of the Round Mountain in Bland County, Va., and about six times between Peak Mountain and the subcarboniferous measures in Tazewell County, in the southeastern edge of the Great Kanawha coal-basin proper, giving us quite a succession of nearly parallel ridges. In the southeastern escarpments of the greater mountains, and doubly in the curved anticlinal of the Round Mountain, we have the ores of the Medina and the Clinton epochs, giving in the long lapse of time since they were thrown up beds of both iron and manganese ores of great value. The manganese ores are derived from two sources, a stratum of silica and manganese oxide combined, nearly about the junction of the Oneida and Medina (the exact location of which I will determine by future observations), and a stratum of

an oxide that underlies it. The iron ore, the red hematite usually, is a reduction from small flattened grains and petrifactions of specular red hematite, in shells of the Clinton, which, in fact, at points is left out. Still, the Clinton has a large development at short intervals, always making the mountain much thicker where it occurs; not only giving a very respectable stratum of ore of the small flattened grains, but also, in places, the most beautiful petrifactions of a perfect shell (Atrypa reticularis, apparently), in specular red hematite, as is the case on the southeastern escarpment of Peters or East River Mountain in Giles County, Va.

In this county, Giles, on the parallel section spoken of in the beginning of this paper, there are extraordinary developments of iron and manganese ores, notably the Sinking Creek veins and deposits, which I will not fatigue you further by giving the measures and analyses of; but neither are objectionable. The red hematite ores, partially magnetic, are at Chapman's and Pack's, on New River, eight feet thick, a portion of them inclosed by brown ores, and showing, by analysis of Messrs. Booth & Garrett, 64.95 per cent. metallic iron and .05 per cent. phosphorus. This vein has been traced by me at intervals for twelve miles. It shows plainly at low water, crossing New River, very clearly defined in the bottom of the stream. On the Angel's Rest Mountain and the opposite mountain across New River are remarkable surface quantities of ores, together with very well-defined deposits or veins in the sandstones, varying from a few inches to many feet, the measures of which I will be pleased to give in a future paper, as well as those of Peters Mountain.

Taking up our cross-section line again and following it N.N.W. to a point about twenty-five miles in an air-line from Wytheville to the crest of the last high mountain (Silurian system), then pursuing our course further, we pass across the remarkably fertile county of Tazewell, Va., eight miles in an air-line across the Bluestone and Abbs valleys, and strike about the terminus of the cross-section into the southeastern edge of the Great Kanawha coal-field proper, which here has a gentle dip inclining to the N.W., the measures aggregating about forty-six feet of coal; one vein being eleven feet with one foot of slate, and another exactly four feet. But these measures are so nearly the same in character as the Upper New River series spoken of in the works of Mr. M. F. Maury, Jr., State Geologist for West Virginia, that I refer you to his admirable papers.

I have not said anything of the valuable salt and gypsum basin,

twenty miles west of our cross-section line. It is hardly necessary. Mr. Lesley, in his report to the Shenandoah Valley Railroad, has very thoroughly explained that. I will reiterate a well-known fact with regard to the gypsum; namely, that it is 800 feet thick in the Holston Valley at one point, formed probably by water charged with sulphuric acid resulting from the decomposition of pyrites in the bordering rocks, coming in contact with the lime carbonates and so replacing the carbonic acid. There are other versions equally plausible.

There are ample quantities of charcoal timber in the region we have had under consideration sufficient to last until the time when stone-coal and coke can be had from Kanawha. If furnacemen in our section would avail themselves of the facts set forth in the paper of Mr. I. Lowthian Bell, lately read before this Institute, there can be no doubt, that with the kindly ores in which this district abounds, a large production of an excellent quality of gray pig can be made at a small cost, allowing a very fair margin even in these times, with transportation over lines that are considered now to be costly to the shipper. Prof. Newberry says: "Charcoal may, however, be produced here in abundance for many years, and the excellent bituminous coals of East Tennessee and West Virginia will be within easy reach. We may expect, therefore, that this will in the future become one of the most important centres of iron production in the United States." May not the same be said with equal truth of the great copper lodes, and the lead and zinc lodes? One of these I have not described, lying in Bland with an extension into Giles County, but not having developments sufficient for measures to be taken; and still another just below the Peters or East River Mountain near New River.

Of the mineral springs for which this region has been famed, I have also said nothing. But where there are sulphuretted strata which also contain other valuable medicinal minerals, it may be inferred that there would be a great many springs of the highest efficiency as medicinal agents. The veins of variegated marble, of lithographic stone, and of corundum will not be forgotten in a future paper.

I hope the mining engineer and the scientist will hereafter visit this really interesting locality more frequently. I know that I express but the real, heartfelt sentiments of the majority of the people of Virginia, when I extend to the guests and members of this Insti-

tute a cordial invitation to come and make themselves familiar with her boundless mineral resources. Though the Virginia people have principally been reared to agricultural pursuits, I have never seen those of my section fail to extend all the facilities in their power to those who earnestly desire to develop her mineral wealth, whatever quarter they might come from. Could we but have the advantage there of the intelligent labor of men like our host of the Philadelphia and Reading Railroad, how short would be the time until our section would teem with the life and the activities that we saw along the route of our late excursion!

PARTIAL RECONSTRUCTION OF A FURNACE CRUCIBLE WHILE IN BLAST.

BY J. H. BRAMWELL, QUINNIMONT FURNACE, WEST VIRGINIA.

THE following experience in rebuilding a furnace crucible while in blast may not be wholly uninteresting to some, notwithstanding its purely practical character. Few are aware of the frequent calls made on a furnace manager's skill and ingenuity, to meet the irregularities which present themselves with kaleidoscopic variations in the operations of furnaces. Unfortunately the methods pursued in overcoming these practical difficulties are too seldom recorded, and much valuable information is lost that could not fail to be of value to many, and to none more so than the educated technical manager, with a limited practical experience, who, without a literature or record of any kind to refer to, finds himself, in times of emergency, dependent and looking for assistance from those whom it is his province to instruct and direct. With positive data, however, that like difficulties have been successfully overcome, he can confidently resort to similar expedients, with such modifications as the circumstances may demand in his particular case, and pull through seeming impossibilities in the face of ignorant prejudice.

The Quinnimont Furnace (60 x 15 feet) had been in operation but two months, when it became necessary to draw the tuyeres out a distance of 18 inches, in order to give them a resting-place; the brickwork under them being completely cut away, so that after each

cast they would sink from 6 to 8 inches, requiring a loss of from 1 to $1\frac{1}{2}$ hours in raising and resetting. The tuyeres had been intentionally retained in their original position as long as practicable, in the hope that the cutting out would be retarded. This, however, did not prove to be the case, the process of destruction continuing as rapidly as ever.

The original thickness of the crucible wall (3 feet) was now reduced to 18 inches, and breaking out of iron was a frequent occurrence. As a still further protection, a wall of brick was carried up, encircling the hearth, with an annular space of 3 inches, which was filled in with fragments of fire-brick, upon which a constant stream of water was kept flowing at several points. This did not suffice to preserve the brick, for, at the expiration of a month, the walls had become so thin that the tuyeres could not be maintained even in their new position without great loss of time in resetting. The quantity of fire-brick and clay used in the operation eventually mixed in with the iron, so that the old experience of fire-brick and iron not working well was repeated with monotonous regularity at each cast. The settling of the tuyeres finally culminated in one falling into the furnace, when it was decided to attempt to rebuild the hearth in sections, and at intervals. A section of the crucible, measuring 7 feet on the outer circumference, 4 feet on the interior, and 4 feet high, was first removed. Commencing at the open tuyere arch, the air was excluded, and stock held back with a heavy body of clay, tightly rammed with fire-brick, and driven back simultaneously with the removal of the old work, and far enough to admit a 30-inch wall being set in with 15-inch blocks, 6 inches thick. The entire operation required 30 hours; quite a flow of cinder and some iron occurred as the last two courses of brick were raised, but was readily removed, and did not prevent a clear foundation being secured 6 inches below the level of the hearth bottom. Two weeks later a section 5 x 3 x 4 feet was taken out on the opposite side, and rebuilt in the same manner, and, later still, repairs of a similar nature were carried out in the back arch. A rising of the brick was anticipated, but did not take place, and beyond a slight bulging no trouble was experienced. The iron was kept very gray for several weeks, giving an excellent opportunity for the work to close up. The furnace was operated seven months longer without exhibiting any signs of weakness. Eventually the cutting out of the boshes necessitated its going out of blast, and on blowing out the renewed sections were comparatively intact.

THE COMPOSITION OF FLUE DEPOSIT.

BY J. BLODGET BRITTON, PHILADELPHIA.

DURING the last three or four years I have had occasion to examine, chemically, various samples of matter commonly called flue-dust or cinder, found deposited in the flues and hot-blast chambers and under the boilers of blast furnaces, and also in the flues and under the boilers of puddling and boiling furnaces.

Recently several of these examinations were made quite in detail, and as the results reveal, I believe, information of no inconsiderable importance, I am induced to communicate them to this Institute.

A sample of deposit obtained from the flues of one of the blast furnaces at the works of the Phœnix Iron Company, at Phœnixville, Pa., was found to have the composition given in Column I of the following table:

Composition of Deposits.	I Dust from Blast Furnace.	II. Dust from Puddling Furnace.	III Dust from Boiling Furnace.
Protoxide of iron,	1.51	3 08	1 18
Peroxide of iron,	20 21	33.29	41 00
Alumina,	6.57	12 89	7 54
Lime,	3.98	.48	.61
Magnesia,	.69	.09	.19
Protoxide of manganese,	1.66	.39	.12
Oxide of zinc,	2.84	....	....
Oxide of copper,	.06	....	....
Silicic acid,	36.00	40.69	38.99
Sulphuric acid,	7.55	1.05	.43
Phosphoric acid,	.94	3.55	2 98
Arsenious acid,	.38	....	....
Antimonious acid,	trace.	....	....
Chlorine,	.03	....	....
Cyanogen,	.09	....	....
Ammonia,	trace.	....	....
Potash with some soda,	16 61	....	....
Carbonic acid,	59	....	....
Alkalies, undetermined matter, and loss,	.29	4 49	6 96
	100.00	100 00	100.00
Metallic iron,	15.31	25 70	29.64
Phosphorus,	.41*	1.55†	1.30‡

* Equal to 2 67 of phosphorus to 100 of iron.
† Equal to 6 03 of phosphorus to 100 of iron.
‡ Equal to 4.72 of phosphorus to 100 of iron.

Nickel, cobalt, chromium, titanium, bismuth, lead, barium, fluorine, and several other substances were also specially searched for, but not a trace of any of them could be found.

The ores used were, I was informed, magnetic and brown hematite mixed. The fuel was Schuylkill anthracite, and the flux was the ordinary limestone of the neighborhood.

A sample of similar deposit, obtained from one of the furnaces belonging to the Crane Iron Company, on the Lehigh, afforded of soluble salts of the alkalies nearly 30 per cent. There were detected in it cyanogen and also chlorine, and a very appreciable amount of carbonic acid, but not a trace of ammonia. A full examination was not made, and only the iron and phosphorus were quantitatively determined. Of the former there was 8.20, and of the latter 0.27 per cent., equal to 3.29 of phosphorus to 100 of iron.

Another sample from the hot-blast chamber of a furnace on the Hudson, belonging to the West Point Iron Company, proved exceedingly complex in composition. It afforded 18.67 of potash, 9.81 of sulphur, or 24.52 of sulphuric acid, but only 5.47 of metallic iron, with 0.34 of phosphorus, equal to 6.22 of phosphorus to 100 of iron.

These two furnaces used anthracite from the Lehigh region, mixed magnetic and brown hematite ores, and limestones from their respective neighborhoods.

In other samples of the material taken from the flues of different furnaces I have found from about 4 to more than 30 per cent. of the alkalies. Upon searching for phosphoric acid, I never failed to find it; sulphuric acid I also found constantly present, and usually in notable quantity.

The material was always, to a large extent, soluble in boiling water, sometimes more than 60 per cent. being dissolved. It was, invariably, readily fusible in the flame of the blowpipe.

These remarks have reference only to the flue deposits from anthracite furnaces. I have no personal experience in the examination of those from coke or charcoal blast furnaces. I should infer, however, that anthracite and coke furnaces afforded deposits of corresponding composition, while charcoal furnaces afforded the material relatively richer in potash and poorer in sulphuric acid.

A sample taken from the flues of a puddling furnace yielded, upon analysis, as given in Column II of above table.

Another sample of deposit, taken from the flues of a boiling furnace, yielded as given in Column III.

The two last samples were received from the works of the Phœnix Iron Company. The iron worked in the furnaces was known to be phosphoric. The fuel used was bituminous coal.

The results quoted would seem to show pretty clearly that more or less phosphorus is volatilized from iron during the processes of smelting, puddling, and boiling. They, beyond question, show that the substance is carried with the dust and fumes from the furnaces into the flues and chambers. And as it is known that limestones and coals usually contain very little of it, it may be assumed that much the larger portion of what was found in the deposited matter came from the ores and metal. That all that passed up from the furnaces became deposited in the flues and chambers cannot be supposed.

It is more than probable that no inconsiderable amount escaped along with its associated matter entirely through the works into the open air. The results so far obtained therefore could be of no value in determining the total per cent. volatilized, even from all the material in the furnaces, though the weight of that material as well as the weight of the flue deposit was known.

But these results present another matter of no less importance for consideration. They show that there is expelled from the blast furnace a very large amount of alkali. Sixteen, eighteen, and even more than thirty per cent. of the gross flue deposit proved to be potash and soda. The question at once arises, From what source or sources did they come? We know that nearly all iron ores contain a little, but usually not enough for the careful analyst to determine quantitatively. And the same may be said with still more emphasis of the limestones. We then must look to the fuel as having been the chief source. It has not, I believe, heretofore been shown by the analyses of anthracites that any of them are rich in alkali; indeed just the contrary has been shown, but this may have been due to defect in the method of analysis. Search has heen confined to the ash only, and not extended to the raw coal or the total product of combustion. The question undoubtedly is worthy of solution.

As the quantity of such flue deposits is considerable, and may be still further increased by alteration of a portion of the works, it is important to consider their practical or commercial value. At present, so far as I know, they are only an object of annoyance and expense by stopping up the flues and chambers, and more or less affecting injuriously the hot-blast pipes and boilers, and must be periodically removed. The practice is, with occasional exception, to throw them away. They may be used with much profit for the pro-

duction of commercial alkali, and also for fertilizing land. As a top dressing for grass they would prove much more valuable than ground plaster.

I infer from the examination made that the alkalies will, in the main, be found in condition as sulphates, silicates, and carbonates, and but to a very limited extent as cyanides or cyanates, and that the composition of the deposit at any one works will be more or less inconstant, and will also vary according to the point at which it forms; thus that which forms in the flues near the furnace will not, by a considerable difference, be the same as that which forms near the exit at the end of the boilers. This would be the supposition from known laws, but the analyses seem to afford proof of it.

WATER IN COALS.

BY J. BLODGET BRITTON, PHILADELPHIA.

SIX different samples of anthracite, each a firm compact lump, were finely pulverized and immediately put in bottles. Portions of these were weighed and placed upon an ordinary water-bath and dried for one hour; the average loss was 1.24. The same portions were then placed in a hot-air oven, and for two hours kept at a temperature of 285° F., and, after cooling in a dry chamber, were again weighed, when there was found a further average loss of 1.22, making a total so far of 2.46. They were then immediately returned to the oven and for two hours more kept at a temperature of 530° F. and cooled and weighed again, when no further loss was found, but an average gain of .55 upon the previous weighing. The same portions were a third time placed in the oven and for about ten minutes kept at the last-mentioned temperature, and then, while still hot, were poured into one-quarter inch glass tubes, each with a bulb at one end, and heated over a Bunsen burner at a temperature below a red heat, when more water vaporized and condensed in small clear globules on the cold parts of the tubes.

Fresh portions of the coals were then taken, and the total amount of water determined, and the average was found to be 3.04, or 1.80 more than was found at the temperature of the water-bath, which was perhaps a little below 212° F., and .58 more than at 285° F.

Tests were afterwards made by placing other fresh portions of the

coals within a bell-glass over strong sulphuric acid for more than twenty-six hours, when the total average loss was found to be 1.91, or 1.13 below the amount of water actually present in the coals. Upon allowing some of these last portions to remain in the open air for a couple of hours, they were found to have nearly regained their original weights. Additional fresh portions were then weighed and left exposed to the open air of the laboratory; the next day they were weighed again, and found to have gained an average of 1.03. This gain proved to be due almost entirely to moisture absorbed.

A sample of bituminous coal from Clearfield County, Pa., was treated very nearly in the same manner. Dried on the water-bath for one hour it lost 1.69; dried in the hot-air oven for one hour at 250° F. the loss was less, being 1.65, and for another hour at 280° F. the loss remained nearly the same, 1.66. Being a third time returned to the oven and kept for about two hours at 580° F., the loss was increased to 2.14. The coal was then tested in a bulb tube over a Bunsen burner below a red heat, and the presence of water was distinctly detected. The actual amount of water in the sample was subsequently found to be 2.46, or .77 more than the loss at the temperature of the water-bath, and .32 more than at the temperature of 580° F.

Another sample of bituminous coal from Huntingdon County, Pa., upon drying on the water-bath for one hour, lost in weight .76, and after being kept in the oven at 545° F. the loss was reduced to .35; upon then being tested in a bulb tube over a Bunsen burner, water was detected. The total amount of water found in this sample was 2.02, or 1.26 more than the loss at the temperature of the bath.

A sample of gas coal from West Virginia gave very nearly similar results. Another sample of the same kind of coal from the Kanawha River, upon exposure in the oven for one hour, at about 560° F., was found not to have lost, but to have gained nearly one per cent. over its normal weight, and then when tested in the bulb tube over a Bunsen burner gave off a very appreciable amount of water.

Quite a number of analyses were made of the true brown coals, or lignites of Southern Arkansas, to ascertain their value for the production of paraffin, and it was found that they did not part with all of their water, which amounted to an average of about 19 per cent., until destructive distillation commenced. A portion of a sample of coal from east of the Rocky Mountains, on the line of the Union

Pacific Railroad, was placed in the hot-air oven, and for an hour and a half kept at a temperature of 170° F., when it was found to have lost in weight 5.72; kept for an hour more at a temperature of 280° F. the loss was increased to 7.31, and again for two hours more, at the same temperature, the whole loss was found to be 7.55. Another portion of the same sample was then subjected for three hours to a temperature of 500° F., when the loss was further increased to 9.55. The watery vapor from this last portion was condensed in a cold glass tube, the tube was carefully weighed and then the water cautiously evaporated, afterward the tube was weighed again, and from the loss the weight of water was ascertained. The coal was then weighed, and its loss was found to correspond very nearly with the weight of the water. Upon immediately testing it in a bulb tube over a Bunsen bürner more water passed off, and upon continuing it over the burner at a high temperature, white fumes and a dark-brown oil passed off, but no more water. The actual amount of water in this sample was subsequently found to be 12.50.

I have made many other experiments, the results of which I need not give in detail; collectively they have tended to prove:

1st. That water exists in the several classes of coals in two conditions, *i. e.*, combined and uncombined, but in these conditions not constant in relative proportions.

2d. That some coals will and some will not, irrespective of the class to which they belong, when finely pulverized and left open to the air, gain in weight by taking oxygen, while at the same time they lose in weight by losing water and hydrocarbons, at temperatures varying between that of boiling water and one that is sufficient for destructive distillation.

3d. That all coals when deprived by heat of any portion of their normal water, will, upon exposure to the open air at common temperatures, immediately begin to regain their loss. It therefore follows that correct weighing cannot be done with the material uninclosed.

4th. That the method of determining the water by merely finding the loss which the coal sustains by drying for one hour at 212° F., or for any length of time, or at any temperature, whether over sulphuric acid or not, gives fallacious results.

THE SOUTHEAST MISSOURI LEAD DISTRICT.

BY PROF. G. C. BROADHEAD, PLEASANT HILL, MO.

THE lead district of Southeast Missouri covers an area of over 3000 square miles, including Maries County on the west, Jefferson on the east, Franklin on the north, and part of Madison on the south, or parts of ten counties.

A general section of the rocks of the southeast part of this region would be about as follows, numbering from the top:

1	Sandstone (the second of Missouri geologists),	20 feet.
2	Chert beds—beds of passage below,	125 "
3.	Magnesian limestone, chert, and quartzite,	100 to 300 "
4	Lower magnesian limestone,	100 to 150 "
5.	Gritstone and lingula beds,	50 "
6	Ozark marble beds,	5 to 20 "
7.	Sandstone and conglomerate,	5 to 90 "
8.	Porphyry, } Archæan.	
9.	Granite, }	

The thickness is approximate, for it is not possible to obtain the correct thickness of the various beds. No. 1 may be seen as detached outliers or loose masses of a hard sandstone or quartzite, and is found on the hilltops in the southern part of Madison County, in like topographical position in Reynolds County and the western part of Washington County.

No. 2 consists of alternations of chert, clay, and quartzite. It is the formation which contains most of the limonite deposits of Central and Southern Missouri. In Reynolds County shafts have penetrated it 75 feet. Outcrops there and in Madison would indicate it to be at least 125 feet thick. Fossils obtained in various places prove it clearly to be of the age of the calciferous sandrock of the New York system, and Nos. 1 and 2 may also be referred to the age of the second sandstone of Missouri.

No. 3 consists chiefly of thick beds of ash, drab and flesh-colored magnesian limestone, both coarse and fine-grained. These beds, where they occur, in Washington, Jefferson, and the southern part of Madison Counties, contain a good deal of quartz in drusy cavities. In Washington County the limestones are beautifully ramified by a system of connected drusy cavities generally lined with minute quartz crystals arranged in botryoidal and mammillary forms, and called "mineral blossom" by the miners. This is the lead-bearing rock of Washington County, but in the southern part of Madison it does not appear to be galeniferous. It is also undoubtedly the equivalent of

the lead-bearing rock of Central Missouri, and is known in Missouri geology as the third magnesian limestone. In Washington County it is from 200 to 300 feet or more thick, but in Madison probably not over 100. No fossils have been obtained from it in these counties. I would here remark that the line of division between Nos. 3 and 4 is not well defined. It may yet be proved that they belong to the same group.

No. 4 consists of either dark ash or flesh-colored dolomitic limestone, generally occurring in thick beds. On Mine La Motte tract, this limestone, with the underlying gritstone beds, is 80 feet thick. At St. Jo Mine, St. François County, it has been proved to be not less than 200 feet thick. At the lead mines it soon becomes brown upon exposure.

At Mine La Motte a thin band of blue shale is found which abounds in a *Lingula* (*Lingulella*) *Lamborni*, which is regarded as a Potsdam fossil by palæontologists. Near Fredericktown the lower limestone beds contain this fossil, together with *Scolithus*, *Orthoceras*, and a *Pleurotomaria*. This is the lead-bearing rock of Mine La Motte, Fox Mines, Avon Mines, and St. Jo.

No. 5 is a close-grained, even-bedded silicious dolomite, sometimes having drusy cavities lined with dolomite. The various beds seem to be chiefly formed of rounded quartz grains disseminated in a compact dolomitic paste. Its greatest thickness amounts to 23 feet, but it is even sometimes wanting.

No. 6, the marble beds, are not always present; for in the northern part of Madison County No. 5 rests directly on No. 7. These beds consist generally of fine-grained, even-bedded, magnesian limestone, of gray, red, flesh-colored, buff, or mottled white, with red, buff, or drab, the colors sometimes quite beautiful. It admits of a high polish and is quite handsome.

The lowest unaltered sedimentary rock of Southeast Missouri is a sandstone, generally coarse-grained, although we do find it of fine grain. It also occurs as a conglomerate, formed chiefly of porphyritic pebbles. Its chief outcrop is in the southern part of St. François and northern part of Madison Counties, especially on the Mine La Motte tract, where we find it directly reposing unaltered on the porphyry, and farther westward on granite. Its greatest thickness is 80 to 90 feet, but is often much thinner. The occurrence of any ore in it is very rare, and only at one place have I heard of a little galena being found.

With regard to the age of these rocks we would call No. 7 (the sandstone) Potsdam. If *Lingula* (*Lingulella*) *Lamborni* is restricted

to the Potsdam group, and the *Scolithus,* also occurring in the same bed with the *Lingula,* we should, without hesitation, regard the rocks as Potsdam, but if these fossils are also found in the calciferous group, we should prefer to assign all our rocks above the lower sandstone, to No. 1, inclusive, as calciferous, for there has thus far been found no well-marked line of division between Nos. 3 and 4, and the late Dr. Shumard stated in his reports that No. 3 (the third magnesian limestone) undoubtedly contained calciferous fossils.

The oldest rocks of Southeast Missouri are the porphyries and granites. We know that the porphyries are older than the above-named rocks, because we have found the lowest sandstone resting unaltered on them, and also upon the granite. We also have found the lowest magnesian limestones resting on this sandstone, and also unaltered upon the porphyry. We therefore have a correct succession of rocks. Our data, thus far, is not sufficient to establish the age of the granites, or whether they are older than the porphyries, but we incline to the belief that they are. Our porphyries, though, are exactly similar to those of Massachusetts and New Brunswick, which are considered Huronian. We, therefore, feel correct in calling ours Huronian. Our granites may be Laurentian.

Ores of the above.—The ores of Nos. 4 and 5 include those of lead, copper, nickel, and cobalt. The oldest worked mines are those of Mine La Motte, where lead was mined soon after the year 1720. At intervals, these mines have been much worked during the present century. The ore occurs disseminated in horizontal limestone beds, throughout an average vertical thickness of 7½ feet. The cap-rock and bed-rock are of like composition, but contain very little ore. In one portion of the mines, copper ore (chalcopyrite) is quite abundant, and is intimately associated with the galena. At another place we find nickel and cobalt quite abundant. This mine having been formerly particularly described, we pass on to others, simply mentioning that at the Avon and Fox Mines the ore occurs very similarly, and that the formation is of the same geological age. At the Fox Mines much of the galena is found in drusy cavities, associated with pyrites, calcite, and dolomite. But it is of the St. Jo Mines that we wish more particularly to speak. As we have stated before, the rocks are similar to those of Mine La Motte, but the ores are only lead and copper. The rock here is a dense ash-blue magnesian limestone, reposing in nearly horizontal strata. The St. Jo Company at present have two working shafts of 80 and 100 feet depth, the ore-bearing rocks being the lower 25 feet, arranged in tolerably uniform layers

of two to four feet in thickness. No vertical veins were observed, but the mineral will sometimes follow vertical cracks. At one place, solid layers of galena, of about three inches in thickness, are intercalated with the limestone beds every few feet; but the ore is generally disseminated in the limestone. In the upper beds, bands of chalcopyrite are of frequent occurrence. A vertical section at one place shows:

1. Several feet of magnesian limestone, occurring in even beds, and containing a small percentage of disseminated galena.
2. 6 feet of magnesian limestone—no galena observed.
3. 3 inches—sheet of galena.
4. 2½ feet of limestone.
5. 3 feet of limestone, with a good percentage of galena.
6. 4 feet—nearly all galena—with a very little limestone.

The Desloge Shaft.—Just adjoining the St. Jo Lead Company's land, and only a few hundred feet northeast, the Missouri Lead Mining and Smelting Company have sunk a shaft 120 feet, and bored 84 feet further, passing through rich galeniferous limestone. A section recorded by the company reports passing through limestone with disseminated galena as follows:

Galena at	. . . . 33½		feet from surface.
" "	 46		" " "
" "	 78		" " "
" very rich at	 78	to 80	" " "
" at	 81		" " "
" a little from	 83	to 97	" " "
" richly disseminated,	 103	to 104	" " "
" sparsely disseminated,	. . . 104	to 114	" " "
" a good percentage,	 114	to 116	" " "
" a very little to	 117		" " "
" a good percentage, from	. . . 117	to 127	" " "
" disseminated, from	 120	to 138	" " "
" very rich, from	 138	to 140	" " "
" disseminated, from	. . . . 140 6	to 140 9	" " "
" fair, disseminated, from	. . . 140.9	to 141 3	" " "
" very rich percentage, from	. . 141.3	to 142	" " "
" disseminated, from	 142	to 151 6	" " "
" very rich, from	. . . . 151.6	to 152.3	" " "
" good, disseminated, from	. . . 152 3	to 154	" " "
" lean, from	 154	to 155.6	" " "
" rich, disseminated, from	. . . 155.6	to 156.6	" " "
" lean, disseminated, from	. . . 156.6	to 157	" " "
" very rich, disseminated, from	. . 157	to 158	" " "
" good, disseminated, from	. . . 158	to 159	" " "
" lean, disseminated, from	. . . 159	to 161.3	" " "
" rich, disseminated, from	. . . 161.3	to 164	" " "

Galena, a little ore, from	164.5 to 165	feet from surface.
" very rich, from	165 to 167	" " "
" mineral, from	167 to 175	" " "
" lean, from	179 to 182	" " "
" disseminated, from	184 to 194	" " "
" very rich, from	194 to 197	" " "
" some mineral, from	197 to 204	" " "

The limestones here lie about horizontal, and it is impossible at present to estimate the probable extent of the galena, but it is undoubtedly very great.

The galena at St. Jo, as at other mines in the lower limestone, is coarsely granular, and cubes are of rare occurrence, but in small drusy cavities very nice crystals of a secondary form are often found. Iron pyrites, dolomite, and calcite abound at the Fox Mines. Calcite and dolomite are of general occurrence; barytes, if at all seen, is very rare.

With regard to the origin of the galena in these mines, we would give as our theory that the limestones were first formed in deep seas. That after and during a long period of subsequent time, the galena, in a state of solution, replaced a portion of the limestone beds which had previously been softened by acids. We would not hazard the opinion that the process of replacement was recent, but rather believe it to have taken place in some remote period of time, and probably before the deposition of the galena among the more recent formations of Southeast Missouri; also, that its formation must have continued through a long period of time, for the galena did not replace the limestone in the different beds at the same time, nor is it certain that the process was in progress in different beds at the same time.

Ores in No. 3, or the Third Magnesian Limestone.—Some of the mines of St. François County, for instance the Vallé Mines, and all of those of Washington and Crawford Counties, occur in these rocks.

The ore occurs either—

1st. In caves or openings.

2d. In leads or lodes.

Cave Openings.—Although there may be a slight difference in the form or shape of the deposits, still I believe that all the galena ores of this formation, excepting the "*leads,*" may come under this head, nor am I certain that the vertical leads should be separated.

The limestones are often bisected by vertical cracks or fissures, crossed by others. These are sometimes narrow, but are often

widened out, probably caused by breaking off and disintegration of masses of limestone. The ore and its associated minerals are limited by "runs" and "openings." The "run" is a widening of the opening, and must not be confounded with the runs of Southwest Missouri. It is limited above and below by solid limestone, which cuts it off from other runs below, sometimes only separated by a few feet, but at other times much more. These runs may therefore be considered as occupying a part of the same crevice, and shut off from each other by closing up of the walls.

At Prairie Diggings, on "Old Mines" tract, we entered a run of 7 feet wide and 55 feet depth, extending in a nearly northern direction as far as explored for several hundred feet. Other short runs or cave openings meet the main run, but generally terminate within a few feet. Others, extending further, develop into similar openings to the main run.

These "runs" or "openings" are filled with masses of decomposed magnesian limestone, barytes, iron pyrites, galena, and calcite, sometimes confusedly arranged, but often in regular broken horizontal layers, the galena generally preserving a nearly horizontal position in its arrangement, and when disseminated, it is found occupying nearly the same horizontal line. The galena is sometimes inclosed by bands of pyrites, and at other times associated with a gangue of barytes, the latter apparently of more recent age.

A vertical section in the main run at one place shows—

1. Cap-rock of magnesian limestone.
2. 1 inch of barytes and galena.
3. 10 inches decomposing magnesian limestone.
4. Streak of iron pyrites.
5. 4 inches of barytes and galena.
6. Streak of iron pyrites.
7. 2-feet mass of barytes, boulders of softened limestone, galena, and streaks of iron pyrites.
8. Bed-rock of magnesian limestone.

At "New Diggings," near Potosi, the galena occurs in a similar association with barytes and pyrites.

The ore at Mineral Point occurs in a very similar manner and in irregular-shaped openings. A vertical section in a shaft displays—

1. Clay and chert.
2. Limestone.
3. Red clay, barytes, and a little galena.
4. 10 inches barytes, in nearly horizontal bands with galena.

5. 5 inches magnesian limestone.
6. Thin seam of barytes and galena.
7. Quartz in drusy cavities and mammillary forms, with some galena attached to the quartz.

The mode of occurrence of ores at New Ishmael, on Palmer tract, is very similar to the last, and to the others just above named. At Mineral Point are interesting exhibitions of replacement of galena by barytes, proven by right angular galeniferous lines traversing barytes. At the Palmer Mines are beautiful forms of calamine crystallized on galena, sometimes entirely enveloping large cubes. The galena at the Palmer Mines also shows drusy cavities, with pretty crystals of cerussite and sometimes also anglesite. The cerussite is sometimes covered by hairlike crystals of barytes.

At Mammoth Mines, in Jefferson County, beautiful specimens can be obtained crystallized in the following genetic succession on magnesian limestone: 1. Quartz in minute botryoidal forms; 2. Iron pyrites; 3. Blende; 4. Barytes; 5. Calcite.

The Sandy Mines occur in what is known as the second magnesian limestone, a group of rocks lying next above our sandstone, which we have spoken of in the first part of this article, but as they occur similarly to other lead deposits we have to speak of, we here insert a brief account of them.

At these mines we find a nearly vertical fissure, varying from a knife-edge to 15 inches wide; the wall-rock is magnesian limestone. The fissure is filled with a gangue of barytes with galena, and has been worked with variable success for many years. The course of the main fissure varies but little from a north and south line, and has been traced for several miles. Parallel to this, and but a few hundred feet apart, are two other fissures, also galeniferous.

Of a similar character is the Jones Mine, owned by the Kansas City Mining and Smelting Company, 15 miles southeast from Versailles, Morgan County. At this place the vein varies in width from 4 to 18 inches, and includes a gangue of barytes in vertical sheets, crystallized at their junction, and bearing galena near its southern exposed portion. It can be traced for three-quarters of a mile north and south. The vein can be easily traced out, but only near its southern exposure is galena found.

In Benton County we find a similar fissure vein, and bearing nearly the same magnetic course, which has also been traced for three-quarters of a mile. Its minerals are iron pyrites, galena, and blende. These "leads," or "fissure veins," originate in cracks in the rock,

probably all owing to the same prime cause, and to the same cause as that which created the place for the "run" on Old Mines tract, and the "runs" or "leads" near Potosi, and the Virginia Mines in Franklin County.

ENDURANCE OF IRON RAILS.

BY W. E. C. COXE, READING, PA.

In 1857 the Philadelphia and Reading Railroad Company, whose main line extended from Philadelphia to Pottsville, Pennsylvania, with branches into the coal regions of Schuylkill County, made a contract with the Fairmount Rolling Mill, at Philadelphia, for the rerolling of some four thousand tons of iron rails. The essential features of the agreement were that the old rails should be piled with puddled iron and rolled into flats for the rail pile, which latter was to be of a section seven inches square, and after being heated, and reduced, by rolling, to a bloom of a section about five inches by six inches, was to be reheated, before being finished into the rail of the T pattern, four inches high, weighing sixty-four pounds per yard. Great care was exercised in the execution of this contract, and the rails being distributed over all parts of the road, gave general satisfaction by their excellent wear. Five years afterward, the principal proprietor and manager of the Fairmount Rolling Mill was elected President of the Reading Railroad, and very many of the rails made under his supervision were still in use in the tracks of the company, of which he had just assumed the management. His first efforts were, therefore, directed to the procuring of more rails of the same quality wherewith to replace those worn out. Here he encountered some trouble, makers refusing to bid because of the details in the specification, the required reheating being the objectionable feature, for which it was generally intimated they would not be sufficiently remunerated for the increased labor, extra coal consumed, and the changes necessary from the established methods of working. Most of the new rails were, therefore, bought, and the old rails rerolled without regard to any particulars as to the manner of piling, heating, etc., each manufacturer furnishing what he deemed the best article possible for the money. As a consequence, rails of all imaginable grades were placed in the tracks, some giving out in six

weeks under a heavy traffic, the majority inside of a year, and very few lasting over two or three years.

So great was the dissatisfaction with the character of the iron rails the company were able to obtain, that in the latter part of 1866 they determined to erect a rolling-mill, and manufacture for themselves. Bessemer steel rails were then coming into this country from England in small quantities, at very high prices, and their use at that time was questionable, but their introduction was considered, and in planning for the mill, engines and trains were adopted of sufficient size and strength for the rolling of steel. Ground was broken at Reading in the spring of 1867, and the first rail turned out in March, 1868.

It was the intention, from the inception of this project, to make a rail of the very first quality, and whilst it was not believed they could be made for any less cost than the market price of an ordinary rail, the profit or gain was in the enhanced endurance of the product. The result has fully justified the wisdom of the policy, and the expenditure for the plant has been more than returned to them directly by the dollars saved in being their own manufacturers, instead of purchasing from outsiders, and indirectly, which is of paramount importance, in the longevity of the rail, requiring less frequent renewals of the tracks, and, of course, a reduction in the expenses for repairs. The Reading Railroad, at the expiration of 1875, owned, leased, and controlled 1550 miles of tracks and sidings. The transportation department requires, for its business, 404 locomotive engines, some of them weighing 38 gross tons, and the majority 30 tons; 14,975 eight and four-wheeled coal cars, equivalent to 22,740 four-wheeled cars; 3520 eight-wheeled and 328 four-wheeled freight cars, and 310 passenger cars.

In addition, the roadway department has in use for construction and repairs, 687 four-wheeled cars. The class of traffic is peculiar, about 60 per cent. being coal, 34 per cent. freight, and but 6 per cent. passengers, the nature of the trade being especially destructive to the permanent way. The rolling-mill constructed by the company consists of 12 single puddling furnaces, with a yearly capacity of 6500 tons of puddled bars, 8 heating furnaces and 2 reheating furnaces, capable of furnishing, in the manner hereafter mentioned, 20,000 gross tons of finished rails annually. It is more especially a rerolling-mill. The method adopted for making the rails was to work about two-thirds old rails with one-third new or puddled iron. Three pieces of old rails are piled on two layers of puddled iron, as

shown by Fig. 3, and heated and rolled into 3 and 4½ inches by 1-inch flats; these form the body of the pile, Fig. 4, being piled so as to break joints 7 inches high. The head-piece is rolled from a 9-inch square pile of these same flats, Fig. 2, heated and rolled into a slab 9 inches wide by 2 inches thick, forming about 22 per cent. of the whole pile. The rail pile thus made up to a section 9 inches square is rolled in three-high 23-inch rolls, until reduced, in six passes, to a bloom 7 inches wide on the base, 5 inches high, and 5 inches wide on the top; the bloom would somewhat naturally assume this shape in course of reduction, but it was more particularly given to distinguish the head part of the bloom from the flange. The bloom is then carried hot to a reheating furnace and wash-heated, preparatory to the final rolling to the finished rail, which is done on a two-high 23-inch train in six passes, a total of twelve passes from the 9-inch pile to the rail 4½ inches high. The use of the puddled iron with the old rails prevents the dryness inherent generally in reworked iron, and insures, with the wash-heating, better welds. The bloom is kept in the reheating furnace sufficient time, say fifteen minutes, to bring it up to a good welding heat. The bloom going quite hot to the finishing rolls is very completely welded in the first three passes, and as the rolling is done in one direction only, the rolls being two-high, it is believed the cinder is nearly all expelled, instead of being retained to some extent by being chased backward and forward, as would likely be done by rolling in both directions on three-high rolls. After the bloom is thoroughly cemented, the cinder being no longer essential, it is well not to retain it in the rail.

It is very evident in the rolling on the two-high train, that the rail comes from the last or finishing pass colder than it would if rolled on the three-high rolls, from the fact of more time being required for the rolling, in carrying over the rolls, instead of passing through a groove, and thus considerable heat is lost. The colder the rail is rolled in the last few passes, the denser and harder will be the metal. In this way an extremely sound rail is obtained, with a good wearing surface.

All the rails are stamped or embossed with the year of their manufacture, and as they are placed in the tracks, the month is also stamped upon them. No old rails are sold by the company, but when worn out or used up returned at once to the mill, and from the stamp upon each rail we get the date of its birth, and knowing the time of death from its return, we can compute the life of the rail. In the annual reports of the President of the Reading Rail-

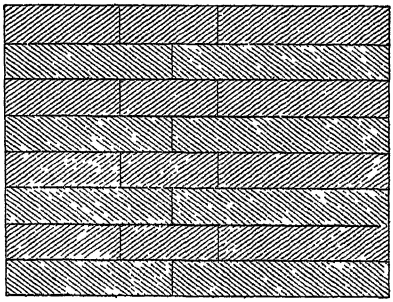
road since 1868, will be seen a statement of the wear of the rails manufactured by the company. From this we learn that out of 9000 tons of rails made and placed in the tracks in 1868, the first year the rolling-mill was operated, only 4500 tons, or 50 per cent., had been returned at the close of 1875 as worn out, leaving 50 per cent. as still in use. In 1869, the second year, 17,000 tons were rolled and put in the road, out of which but 4000 tons, or 24 per cent., have been condemned as used up and returned for rerolling, leaving 76 per cent. still in use.

As it is probable that some of the first two years' make, although too much worn to be of service in the main tracks, were sufficiently good to be placed in the sidings, instead of being sent back to the mill, no estimate is made of the tonnage carried, but, passing to the third year, 1870, the product being 17,500 tons, we find only 3000 tons, or 17 per cent., have been condemned as worn out, and taken from the tracks, leaving 83 per cent. of that year's make still doing service after six years' use, having carried some 50,000,000 gross tons, inclusive of weight of engines and cars. It should here be stated that, at the expiration of the year just mentioned, the weight of the rail was increased from 64 to 68 pounds per yard, more metal being put in the head, with the expectation of making it still more lasting. The product of 1871 was 19,000 tons, 92 per cent. of which can now be found in tolerable condition after having borne 5 years' traffic; and of the product, 20,000 tons, of 1872, only 6½ per cent. have been worn out, under a tonnage of 35,000,000.

Since 1872 the make has averaged 15,000 tons per annum, but owing to the remarkable endurance of the rails previously made, all the new rails manufactured in 1873, 1874, and 1875 have not been laid in the track, and the percentages of the removals are not quite as accurate as those already mentioned. This generally would seem to show the uniform excellence and durability of the rails turned out by the process described. Late in 1869 it was decided to make some particular tests of rails manufactured in the usual way, with the exception of leaving the old rails out of the head-piece, and substituting some special brands of pig iron, worked alone for this purpose. In January, 1870, these rails were placed in the down track of the main line, above Reading, near the rolling-mill, where they would be required to carry most of the immense tonnage from the coal regions, and where they could be frequently observed by the writer, and their wear carefully noted. The method of making these rails will now be described. Referring to the sketch (which shows

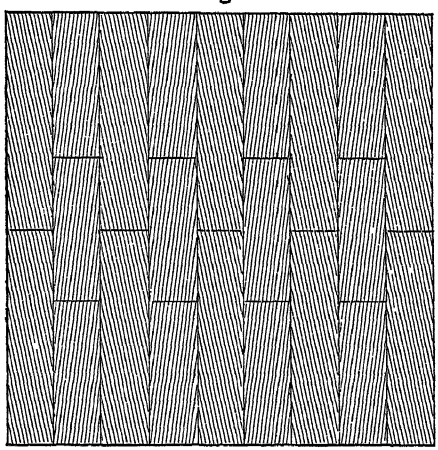
the sections $\frac{1}{4}$ size), Fig. 1 represents a pile made from muck-bars, puddled against soapstone compressed in the rotary squeezer, and rolled into flats $4\frac{1}{2}$ and $3\frac{1}{2}$ by $\frac{3}{4}$ inches, and piled, breaking joints, 8

Fig. 1



inches wide by 6 inches high; this is rolled into flats $4\frac{1}{2}$ and 3×1 inches, and formed into a pile of a section 9 inches square, as shown in Fig. 2; some of these piles were rolled flat or horizontally, and

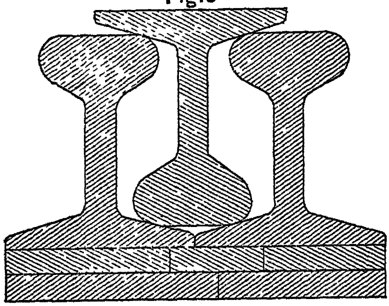
Fig. 2



others on edge, or vertically, into head-pieces or tops 9 inches wide by 2 inches thick. The body of the rail-pile, Fig. 4, is made up of $4\frac{1}{2}$ and 3×1-inch flats, rolled from a pile of three pieces of old rails, and four pieces puddled iron, as shown in Fig. 3. The rail-pile (Fig. 4) thus made up of a section 9 inches square is rolled into a bloom (Fig. 5) 7 inches at base, 4 inches on top, and 6 inches high, with the head at the top, and charged into a reheating furnace and

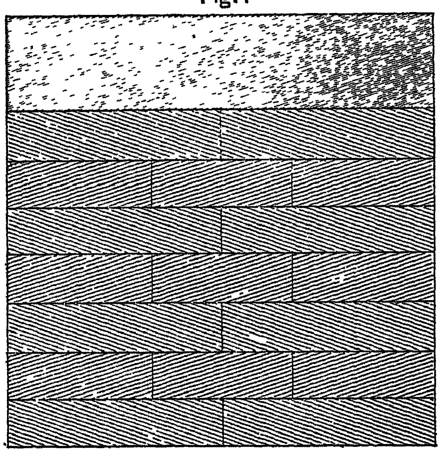
wash-heated before final rolling in the two-high rolls to the rail section (Fig. 6). The rolling of some of the piles for the heads (Fig. 2) on edge, so as to bring the welds vertical, instead of horizontal, in

Fig.3



the finished rail, was for the purpose of comparing the two methods. In the horizontal piling most of the failures arise from lamination.

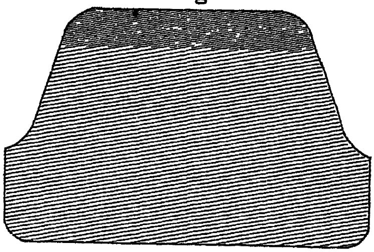
Fig.4



The best results followed from the edge-rolling. The welds, although vertical, in the heads of the finished rails are in practice rolled horizontal, from the manner of the rail going through the last three passes on its side, the vertical pressure more thoroughly welding the head. Twelve varieties of pig iron were selected for trial, 9 from the Schuylkill Valley, 2 from the Lehigh, and 1 from the Susquehanna. Pieces were taken from the different kinds after being puddled, and once reworked, and tested for tensile strength. The maximum being

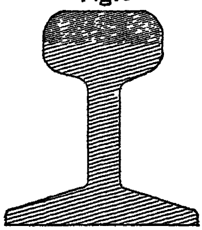
66,000 pounds, and the minimum 45,000 pounds to the square inch. They were divided into three classes: The neutral irons with ten-

Fig.5



dency to cold shortness gave an average tensile strength of 63,200 pounds; the red-short, 60,700 pounds; and the cold-short, 52,500 pounds. These were again arranged in two lots, those with heads

Fig.6



rolled flat, and those with heads rolled vertical, and the tonnage, including weights of engines and cars actually carried by each kind before it was worn out, was as follows:

	Rails with heads rolled flat.	Rails with heads rolled vertical.
Total average, ...	25,324,348 tons.	30,040,670 tons.
Red-short average, . . .	26,959,808 "	22,819,300. "
Neutral average, ...	22,412,593 "	28,789,361 "
Cold-short average, . . .	26,645,538 "	33,472,600 "

From this we gather that the cold-short irons rolled on edge show on the average the most endurance. The lot of rails doing the best was removed after six years of service, during which time 55,000,000 tons passed over them. One of these rails carried over 56,000,000 tons, and was taken from the tracks before being absolutely worn out to be placed on exhibition at the Centennial Exposition. The hard, fine-grained, cold-short irons are more durable

than the softer and stronger fibrous irons of a red-short nature. The cold-short irons appear to give the best welds, and the stronger they are the better. The iron in the heads of the rails bearing the maximum tonnage was from a blast furnace in the vicinity of Reading, and was smelted from a mixture of 60 per cent. East Penn hematites, 25 per cent. Tilly Foster, and 15 per cent. East Penn magnetic ores. The analysis of this head iron gave

Phosphorus,	.422
Silica,	.392
Sulphur,	.032
Manganese,	.164
Carbon,	.027
Iron,	98 963
	100.000

In the same track with these experimental bars were laid some rails with the heads formed of a solid hammered charcoal bloom, with the expectation that, being without welds, they would show a wear almost equal to steel, but they gave out under a tonnage of 28,000,000. As the iron was too soft from lack of sufficient rolling they mashed out in spots under the heavy traffic. Puddled steel-headed rails have not done much better from the same causes. Some excellent results were obtained from steel-headed rails made by welding Bessemer and open-hearth or the Siemens-Martin steel slabs on to an iron base, but as the purpose of this paper was to deal with iron rather than steel, inquiry in this line will not be extended further.

Whilst admitting the vast superiority of steel for rails required to stand a very heavy traffic, iron, if carefully selected and properly manufactured, has a capacity for which it seldom gets credit. At the present time it is possible to make iron rails by the method described at considerably less than the price of steel rails, and as a matter of economy it is of vast importance to roads with an ordinary traffic to consider whether they shall substitute steel for their old iron rails, disposing of the latter at a sacrifice, or have them re-rolled by the process adopted by the Philadelphia and Reading Railroad.

MR. HOLLEY asked if, in regard to expelling the cinder, it was not equally important to roll the pile on a two-high mill as to make the finishing passes of the rail on the two-high mill?

MR. COXE replied: It is better to retain some of the fluid cinder in the pile until after it has been bloomed and reheated, in order to perfect the weld. Rolling in the three-high in the earlier stages favors the retention of the cinder. Some of the cinder is of course thrown out in the first rolling on the three-high, but enough is kept in to act as a cement when it comes to the two-high finishing rolls from the reheating furnace. We think we get the cinder very thoroughly expelled on the two-high mill, more so than on the three-high. We have also tried three-high rolling for the rail finishing. Some two years since we got up a set of three-high rolls for rolling steel ingots. We put half of our furnaces on steel and half on iron. It is very noticeable in rolling iron on the three-high rolls that not so much cinder is expelled as on the two-high.

MR. FIRMSTONE.—Do the rails with vertical welds in the head ever split down in a line with the neck?

MR. COXE.—This has not occurred since these experiments were made. We thicken the head of the rail by building up underneath, thereby overcoming the difficulty. A glance at the diagrams will show that the head-bar or cover does not run down to more than one-half of the thickness of the head of the rail, the vertical piled head-bar being supported by the horizontal piled iron underneath.

In answer to a question whether cinder is not more effectually expelled by alternately rolling backwards and forwards, Mr. Coxe remarked: The cinder must be expelled from the ends of the pile. This should be done in one direction, and the tendency of the cinder is then to flow and be ejected from one end. If the pile is reversed, or rolled in the opposite direction, the flow of a portion of the cinder is changed, and forced to the other end, and thus some is retained in the middle.

DR. WEDDING.—This is the reverse of our opinions and practice. The effect of rolling in one direction is to accumulate cinder at one end of the pile, while reversing tends to its more even distribution and expulsion.

MR. COXE.—There is no doubt that there are more crop ends when rolling two-high than when rolling three-high, and the former is moreover much more severe on the iron. We are required, in consequence, to use a higher and better class of irons.

MR. HOLLEY.—Is it not the most important element in the manufacture of iron rails that plenty of work should be put on them?

Mr. Coxe.—Yes; the iron should be as much condensed as possible.

Mr. Holley.—Is it not possible to take inferior irons, and by the process you describe—reworking the iron frequently—to produce a very good rail?

Mr. Coxe.—I cannot tell. We have never used what we consider an inferior iron.

Mr. Reese agreed with Mr. Coxe in the importance of selecting good iron. He had tried by repeated workings to counteract the original poor quality of an iron, but had generally failed. Careful selection of materials was essential in iron manufacture.

Mr. Coxe.—For the benefit of some of our friends present I would add that our high averages were obtained with irons fiom Glendon and Monocacy furnaces.

Mr. Britton.—I would like to refer briefly to some results of analyses made by me several years ago. In order to ascertain the constituents of good and bad rails, with a view to publication, I addressed notes to the Pennsylvania Railroad Company, the Philadelphia and Reading Railroad Company, and the Philadelphia, Wilmington and Baltimore Railroad Company, and in response obtained a number of samples (short sections) of rails that had been in actual use, the histories of which were known. They were of all qualities, good, bad, and indifferent. The first batch received was, according to my recollection, from the last-named company. It included some of the Welsh rails, originally laid, I was told, in the track of the Frenchtown and New Castle road in Delaware. Some of these rails had been in use for about twenty-eight years, and others for thirty-two years, and when eventually taken up, after several removals, and being no longer fit for use, were found to be not broken, cracked, split, or crushed, but worn out by abrasion merely. Their tops were mostly smooth and their edges sharp. The iron in them was thought to be peculiar. It was supposed to be homogeneous. Each rail, it was believed, had been rolled from a single billet. In order to test whether this last was the case or not, the ends of several of the samples were filed straight off and polished, and then dipped for a short time in dilute nitric acid; and upon removal were quickly washed, wiped dry, and oiled, when the piling of the metal was readily seen. The lines were fine and beautifully distinct; the welding was perfect. Of these samples one hundred and two analyses were made. The average amount of phosphorus found was about .32 per cent.,

the carbon .06 per cent., a very little sulphur, and some silica, due to slag. There would have been no silicon, I apprehend, after such repeated working as the iron must have had. Practically there were no other impurities. The top part and bottom part of each sample was analyzed separately. There was some difference, but very little. Many of these Welsh rails, when taken up, were used, I was told, for making car-wheel axles and bridge rods, so good was the iron found to be. When I came to examine some of the other samples, I was very much surprised. Portions from the top, the neck, and bottom were separately analyzed. One sample from the Pennsylvania Railroad, if my recollection is correct, which claimed an excellent record, had upon the top a very cold-short iron, made, it might have been, from cinder pig. In the neck the constituents were quite different, indicating a bad iron, though tough. In the bottom the constituents were again different.

The examinations of the samples were numerous and laborious. The conclusions arrived at were that a very good rail may be made from several very bad irons, if properly arranged; that is to say, the top of the rail may be made of a hard, cold-short iron, which will give wearing quality, and the under part of the head, the neck, and flange, of irons of different qualities, but possessing toughness; yet each one in itself, for many purposes, may be worthless, and alone would be condemned for rail-making.

The speaker referred to some rails with heads of quite cold-short phosphoric iron made at Milwaukee, which wore well.

THE KIND-CHAUDRON PROCESS FOR SINKING AND TUBBING MINING SHAFTS.

BY JULIEN DEBY, C.E., BRUSSELS, BELGIUM.

The sinking of a deep shaft is always a serious undertaking, especially when the strata to be traversed are of great hardness, or when they are feebly coherent or highly saturated with water.

In the first case, that of solid rock, modern appliances, such as the rock-drill, put into motion by air-compressors, along with suitable explosives, will generally answer the purposes of the mining engineer until he has reached the main water-levels. When these have

been attained, powerful and expensive pumping or hydraulic machinery comes into immediate requisition, and engines are often, at this period of the undertaking, expected to perform a higher amount of duty than any previous computation could foresee, and for which they may consequently prove inadequate. Thus frequently arise disappointment and serious trouble, both technical and financial.

If, on the contrary, the valuable minerals are overlaid by ground of a crumbling consistence, liable to "cave" or to "run," or which is drowned in a body of water, the success of sinking a shaft by the ordinary methods of mining is in most cases problematical, or at the best constitutes an undertaking of great difficulty; and when bored through such material, the shaft is always sure to prove leaky, and the mine below to contain much water, both of which constitute sources of permanent expense in the future, as well as of continual danger and discomfort to the miner.

Most sandstones, gravel and flint beds and deposits, many clays and friable limestones and marls, the chalk formation from the greensands to the white chalk, the Jurassic and Triassic formations, the tertiaries, quaternaries, and recent deposits, including most river-beds, ancient and modern, belong to this class of what miners have long known by the denomination of "bad ground."

Such unsatisfactory regions occur in all parts of the world. We find them abundant in the province of Hainault, in Belgium, overlying the coal measures; in the department of the Nord and of the Pas-de-Calais, in France; in the department of the Moselle; in the Valley of the Ruhr, in Westphalia; in Staffordshire and elsewhere in England. In the United States much valuable mining property remains unexplored and unproductive from the difficulties attending the sinking of shafts through water-bearing strata. We find localities of this description in the valleys of the Lehigh, of the Susquehanna, of the Monongahela, and of the Lower Mississippi, the first in the coal and anthracite regions, and the latter overlying, apparently, beds of sulphur of vast thickness and of immense value.

In the year 1849, M. Kind, an engineer, well known by his success as a well-borer, imagined that he could go through any kind of strata mechanically on the largest scale. The only thing needed to effect this being, as he supposed, the employment of sufficiently powerful and weighty tools. This idea had, however, previously been enunciated by Prof. Combes, as early as 1844, but had never been put into practice.

M. Kind soon took out letters-patent for his apparatus, and be-

tween the years 1849 and 1854 he undertook to execute the sinking of three shafts through water-bearing strata by his new method. Two of these were situated at Stiring-Wendel, in the department of the Moselle, and the third in the valley of the Ruhr, in Westphalia.

It would be useless for us to give here full details of the eventual failure of all these attempts, attributable in part to the inefficiency of the tools employed, but more especially to the impossibility of making any kind of wooden tubbing or casing tight at the horizontal joints, or sufficiently strong to resist the tremendous outside pressure. Although staves twelve inches thick were made use of, carefully banded together by means of iron hoops, they in every instance eventually gave way, causing the loss of the shaft. The addition of an external coating of twelve inches of concrete had no useful effect in preventing disasters. The subsequent trial of the boiler-plate tubbing also proved inadequate to meet the emergencies of the case.

In the year 1849, M. Mulot, the well-known engineer of the Grenelle artesian boring in Paris, attempted to sink a colliery shaft by mechanical means in the Pas-de-Calais. He failed also signally through the imperfection of his tubbing.

All mining engineers on the continent of Europe now hastened to condemn M. Kind's and every other process for sinking shafts by mechanical means through water-bearing strata, and they would, according to all probability, have passed forever into oblivion, had not M. J. Chaudron, an eminent Belgian engineer, taken up the study of the whole question where it had been nearly abandoned by its first promoters.

He soon modified most of the details in the construction of the boring tools, and replaced the inefficient wooden and sheet-iron casings by one formed of a series of superimposed heavy cast-iron rings. These he found it was a practical necessity to employ in a single piece and not in sections, and with flanges carefully planed on the surface of contact. Every separate ring was next tested as to its resistance by means of *external* hydraulic pressure, which proved to be a most necessary precaution, as many rings were found to be defective from imperfections in the castings. The formula employed by M. Chaudron for determining the thickness of his tubbing at various depths below the surface is the following:

$$E = \frac{R \ P}{K}$$

In which E is the thickness required, R is the external radius in

decimal metric measure, P is the pressure to be supported in kilograms per square centimeter, and K the coefficient of resistance to crushing force of cast iron, and which M. Chaudron fixes at 500.

In order to make assurance doubly sure, he adds 0.02 m. to the value of E, and obtains thus his practical or working formula:

$$E = 0\ 02\,\mathrm{m.} + \frac{R\ \ P}{500}$$

which may be fully relied on in all cases.

M. J. Chaudron did not limit his labors to devising the boring of a shaft and the subsequent introducing into it of a solid cast-iron column, but he added to his ingenious apparatus the only rational appliance for sinking, vertically and simultaneously, such an apparently unwieldy assemblage of cast-iron rings, the total weight of which often surpassed several hundred tons. This he did in a very clever manner by suspending or floating the whole system upon the surface of the water in the shaft by means of a false bottom, adapted to the lower part of the huge cast-iron tube. He still further perfected the process by introducing beneath this false bottom a stuffing-box, or as he calls it, a "moss-box" (*boite a mousse*), filled with moss, and of the same diameter as the outer tubbing, which constitutes, when the casing has finally reached the bottom of the shaft, a perfectly water-tight joint, shutting out permanently from the workings in the mine below all water, either stagnant or flowing around the outer walls of the shaft. We refer the reader to Appendix No. I to this paper for a short notice of the principal tools employed in the boring, and of the tubbing used by M. J. Chaudron in his more recent and successful undertakings.

Soon after this gentleman had fully ripened his plans he undertook the contract for the sinking of two shafts for the *Société de Péronnes* in Belgium, a company which had, since 1827, spent immense sums of money in vainly attempting to reach the coal-seams. These two shafts were known as No. 3, *Saint Vaast*, and No. 2, *Sainte Marie*. The first was to reach a depth of about 405 feet, the second of about 350 feet. The operations once commenced were carried on day and night. The body of men employed comprised, as is usual when the Chaudron process is followed, one chief foreman, one blacksmith and his striker, besides two shifts of six men each, consisting of an engine-driver, a fireman, a boss workman, and three ordinary laborers under the orders of the last.

The ground to be traversed consisted of beds of marl, with heavy

layers of flint and chert, of greensands, of argillaceous glauconites, of sand, and, in fact, all the lower measures of the cretaceous formation.

These shafts were bored in two successive operations, the first bore of small diameter being subsequently enlarged to its permanent dimensions.

The shaft No. 3, *Saint Vaast*, was bored to a diameter of about 4½ feet, and to a depth of about 405 feet. This was done in the course of 121 working days. The widening of this shaft to 14 feet to a depth of 315 feet, where a good supporting bed for tubbing was met with, required seven months.

An examination of a careful record of operations gives us the following figures for the relative periods occupied by the different parts of the process. During the boring of the small preliminary shaft, 56 per cent. of time was taken up by the operation of boring proper; 14½ per cent. in lowering and elevating the boring tools; 19 per cent. in dredging out the refuse; 10½ per cent. in stoppages for change of tools, accidents, and for necessary repairs.

The average advance for 24 hours was equal to 81 centimeters, and would have been greater had not the tools or trepans been rather too light for the work to be done. During the widening of the shaft from 4½ to 14 feet, 42 per cent. of time was occupied in the boring proper; 11 per cent. in lowering and raising the boring tools; 21 per cent. in dredging; 8 per cent. in occasional work with the smaller boring tools; 18 per cent. in changing tools, repairs, and accidents. The average daily advance was here only 32 centimeters, much time being lost by the use of a too small sand-bucket, and of boring tools deficient in weight.

The general summary shows that this shaft was finished to a depth of 405 feet, with a diameter of 4½ feet, and widened to a depth of 314 feet to a diameter of 14 feet, in the short space of 12½ months from the day the work was begun. During this period fully two months of stoppages occurred from accidental causes.

The cast-iron tubbing lowered into this shaft had a total height of 204 feet, and weighed 245 tons. The whole of the tools and machinery employed did not cost more than $14,000, and the total expense of the shaft, when completed, about $44,000.

The cost of buildings and foundations, most of which remained *in situ* for the permanent working of the mine, amounted to 24,454 francs; the expense of boring the shaft, to 51,235 francs; the cast-iron tubbing in place, to 127,646 francs; the sinking fund, to 17,000

francs; in all, 220,336 francs. Subsequent shafts, proportionately to their depth and to the amount of iron tubbing placed in them, cost a less sum of money for their execution.

The shaft No. 2, *Sainte Marie,* intended as a ventilating shaft, was first sunk to a depth of 325 feet, with a bore of 4½ feet, and widened afterwards to 7 feet to a depth of 315 feet. The work, begun on the 27th of June, was entirely completed by the 29th of January following, or in less than seven months, although nearly four weeks were lost by the necessity of repairing a serious accident, namely, the deviation of the shaft from the vertical. The iron column in this shaft had a height of 186 feet. In this case the total cost of the shaft was established as follows:

Buildings and foundations,	10,091	francs,
Boring proper,	18,581	"
Cast-iron tubbing, etc.,	29,785	"
Sinking fund,	6,000	"
Total,	64,457	"

Or in round figures about $13,000.

The next two shafts undertaken by M. Chaudron were those of L'Hôpital, in the department of the Moselle. These had to be bored through the tough but highly water-bearing sandstones of the Vosges, as well as through the various strata of the new red sandstone, including its basal conglomerates of exceeding hardness. More than 21 millions of francs had been spent in this very locality within a short period of years in unsuccessful attempts to reach the coal underlying these rebellious strata.

One of the shafts of L'Hôpital was to be 480 feet deep, and 12 feet in diameter, the other 5½ feet wide, and the same depth as the preceding. The larger shaft was started on the 9th of June, 1864, and completed on the 21st of November, 1866. The smaller shaft was begun at the end of 1862, and finished in December, 1865. The difficulties to be contended with during the boring of these shafts, through much harder ground than had ever before been attempted by the Chaudron process, were very considerable, but the intelligence and perseverance of the engineer in charge finally overcame all obstacles, and the work was brought to a very satisfactory conclusion, at a cost of $30,000 less than had been established by the preliminary estimates.

The large shaft contained 635 tons of iron tubbing, and the smaller 258 tons. The cost of these shafts, complete, was $88,000 for the larger and $51,200 for the smaller one.

On the 9th of July of the same year, a shaft 273 feet deep was begun by the Chaudron process at *Sainte Barbe*, and was entirely finished on the 7th of January following. This shaft contained a column of cast iron 168 feet in height, weighing about 200 tons. The total cost of this shaft, including a certain amount of temple-tubbing rendered necessary by the presence of a remarkably liquid bed of quicksand, amounted to about $30,000.*

The Chaudron process was next introduced into Germany, at Dalbusch, in Westphalia, in the valley of the Ruhr. Two shafts were sunk there, the one a working shaft 12 feet in diameter and 302 feet deep, and containing 302 feet of tubbing, the other a ventilating shaft. Both were carried to a rapid and successful termination, at a total cost of about $111,000 for the two. We may add that since this period, the same company has added three new shafts to its previous two, all of which have been bored and tubbed by the same Chaudron process.

The Kind-Chaudron method was now generally recognized as a great success, even by the most incredulous of its former adversaries, and its employment soon spread rapidly.

In 1868, Escarpelle followed with two shafts 338 feet deep; in 1870, Maurage, with two 626 feet deep; in 1872, Lieven, with three 290 feet deep; Meurchin, with two 298 feet deep, and Douchy with one 115 feet deep; in 1873, Vendin, with one 365 feet deep and two 285 feet deep; Anniche, with one 298 feet deep; Marles, with two 400 feet deep; Ciply, with two 285 feet deep; and Dalbusch, with three 302 feet deep; in 1874, Bruay, with two 400 feet deep; in 1875, Crespin, with one 368 feet deep. During the present year, we have Escarpelle with two new shafts, sinking to a depth of 338 feet; Dax, in the department of the Landes, one to an unknown depth; Ghlin, near Mons, in Belgium, two 760 feet deep; Braquenies, in Belgium, two 721 feet deep; Cannock, in Staffordshire, two 394 feet deep; Sarre, in Alsace-Lorraine, three 520 feet deep; Marley, one, depth unknown.

The total number of shafts completed or in course of sinking by the Chaudron process is 43, the total sum of the borings amounting to nearly 10,000 feet.†

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* For further details regarding the cost of sinking mining shafts by the Chaudron process, see Appendix No II, to the present paper.

† See Appendix No. III for a tabular statement of all the shafts sunk by the Chaudron process to this date, with indication of their depth, of the amount of temple-tubbing and of case-tubbing employed in them, and of the duration of the operations of boring and tubbing them.

Every shaft sunk to this day by the Chaudron process in Europe, without a single exception, has resulted in a success. All have kept water-tight and have resisted external pressure, and are this day giving the greatest satisfaction to their owners.

The boring of a mining shaft through even the most highly water-bearing strata need no longer be dreaded by any mining engineer who thoroughly understands the working of the Chaudron process. The whole profession owe to this eminent and enterprising engineer a debt of gratitude for his really very important contribution to the science of mining technology.

In conclusion, we may summarize the advantages of the Chaudron process over the older methods of mining under the following heads:

1. The water from all the water-levels situated above the bottom of the tubbing is isolated and kept permanently excluded from the shaft as well as from the workings below it.

2. The solidity and durability of the shaft are very great, and much superior to that obtained by any other means.

3. The cost of sinking a shaft through water-bearing or caving strata is reduced to a minimum.

4. A great saving in time is realized.

5. The possibility, not to say certainty, is obtained of traversing, without much difficulty, any number of successive water-levels and any kind of water-bearing strata without having recourse to any pumping machinery whatever.

6. The absence of all danger and inconvenience to the miner during the operation is complete, and contrasts with the perils and discomfiture attendant on the ordinary mode of sinking shafts below the water-level.

7. Safe and reliable preliminary estimates as to the cost of sinking a mining shaft through unpropitious ground are attainable only by the adoption of the Chaudron process.

Appendix I.

The principal tools used in boring mining shafts by the Kind-Chaudron process are the following (see Plate I): The trepans, the object of which is to disintegrate the rock by concussion. These are attached to the extremity of a series of wooden rods with iron armatures and screw ends, fastened to the extremity of a balance or striking beam, put into motion by means of a single-acting or bull-engine worked by hand.

Sand-buckets, which are large plate-iron cylinders with valve bottoms and handles, which allow of the dumping of their contents, are made use of to dredge the dirt and slush from the bottom of the shaft as the work progresses.

Shafts are bored by the Chaudron process in two and occasionally in three successive operations. The first bore is made by the small trepan, generally about 4½ feet in diameter, through which the detritus is extracted until the final completion of the shaft. This first bore is then widened by the use of the large trepan.

The apparatus employed in case of accidents or of special emergencies comprise a safety-hook, a grappling forceps of very ingenious construction, and the fanchere (fangsheere) or holding nippers.

The small trepan is formed of two distinct portions, the blade and its stem. The first is made of a solid block of forged iron, into the lower portion of which is inserted a number of steel or chilled teeth of a wedgelike shape, held in place by conical keys. The stem is attached to the blade by another set of strong keys, and to the suspension appliances by means of a sliding box. This last is a very important part of the apparatus, as without it the violent vibrations transmitted by the concussions of the trepan on hard rock would inevitably rupture the connecting rods at every blow. The weight of the small trepan varies according to the work to be done; that on exhibition at Philadelphia this year weighs 15 tons. In trepans as first constructed by M. Kind the upper portion of the central stem was threaded to receive a screw which united to the slide, but this arrangement gave much trouble and soon got out of repair, and has subsequently been replaced by an adaptation consisting of two plates keyed permanently to the stem, replacing the male portion of the older model. The large trepan, employed for widening the bore made by the small trepan, consists also of a ponderous forged-iron blade, carrying teeth at its two extremities, and a V-shaped guide, of the diameter of the small bore, situated in the central or toothless portion. This blade is united to the central stem by three arms strongly keyed. The weight of this tool as made at present is about 25 tons.

The whole apparatus employed in sinking and tubbing a mining shaft by the Chaudron process is operated by means of two engines, the one destined to raise the trepans during the act of striking, the second to work a capstan which is used in the lifting and lowering of the various tools and of the tubbing.

We refer practical engineers for minuter details to M. Chaudron's

able papers entitled "Foncage des puits a niveau plein," published in the Annals of Public Works of Belgium, and limit ourselves to the reproduction of drawings of the apparatus used (see Plate I):

Fig. 1. Sand-bucket or dredging apparatus.

Fig. 2. Safety-hook for lifting the trepans and their connecting rods in case of rupture of these last.

Fig. 3. Grappling-hook for extracting blocks of rock, detached teeth from the trepans, etc., from the bottom of the shaft.

Fig. 4. Fanchere, replacing the safety-hook in the event of a rupture of the main stem, or of that of one of the rods below the prominent collar at its head.

Fig. 5. Small trepan used at L'Hôpital for a first bore of 1.37 meter diameter.

Fig. 6. Small massive trepan for the same purpose, but in hard rock.

Fig. 7. Widening trepan with a double blade, used in the air-shaft for a diameter of 2½ meters.

Fig. 8. Large trepan for hard ground.

g g. Central guide occupying the bore previously made by the smaller tool, and maintaining the apparatus in a central position.

Fig. 9. Large trepan for boring diameters of from 4.10 to 4.25 meters.

Fig. 10. Large trepan, made by adding a blade to trepan No. 7.

Fig. 11. New form of trepan proposed by M. Kind for diameters of 0.70 to 1 meter through hard rock.

Fig. 12. Trepan for a first widening of the shaft to 2½ meters in diameter.

Fig. 13. Large trepan shafts of 4.20 meters in diameter, with teeth arranged on an incline so as to direct the débris of rock to the centre.

Fig. 14. Small trepan for bores of 1½ meter in soft ground.

Fig. 15. Large trepan for widening the above in soft ground.

Fig. 16. Kibble for receiving débris, proposed to be suspended in the shaft during the work of widening.

Fig. 17. Vertical section of the moss-box as fitted to the tubbing of shaft No. 2 of L'Hôpital.

a a. Internal cylinder, carrying a flange at the bottom, forming the wall of the moss-box. This cylinder is suspended by means of six screw-bolts, which allow of its gliding on them as guides during compression.

b b. First section of the tubbing, which carries an outer flange and forms the other wall of the moss-box.

s s. Iron (sheet) segments, which press on the moss and prevent exclusive vertical compression of the same.

m. Moss contained in the joint before compression.

Fig. 18. Assemblage of the parts which constitute the lower end of the tubbing. This portion alone is lowered to the surface of the water before the series of rings of the tubbing are adapted successively to it.

a a. Internal wall of the moss-box.

b b. First section of the tubbing, forming the outer wall of the moss-box.

c c. Second section of the tubbing, which carries the false bottom and eventually floats the whole column.

d d. Third section of tubbing, with the suspension flanges which attach to the guide-rods for the maintenance of the system in a vertical position while sinking.

f f. Central pipe, adapted by its lower end to the centre of the false bottom, and which is carried to the top in successive lengths along with the outer tubbing; water being allowed to penetrate by means of suitable cocks inserted at various heights in this tube, permits of the gradual and simultaneous lowering of the whole casing independent of its weight. When this has reached the bottom, and the moss-box has closed by compression, the water is pumped out of the shaft, and the false bottom and central tube extracted, after which the permanent foundations are established. Before, however, the water is taken out of the shaft, a coating of concrete is introduced between the tubbing and the outer walls of the shaft, and permitted to harden there. The shaft is now found to be perfectly tight in all its parts, if the work has been properly conducted.

Fig. 19. Foundation for the tubbing as established at L'Hôpital.

Fig. 20. The same for the shaft of Sainte Barbe.

Fig. 21. Special ladle for the introduction of the concrete. This tool is furnished with a movable bottom, connected to a piston-rod in such a way that pressure on the latter causes the evacuation of the contents.

Appendix II.

COST OF SINKING SHAFTS BY THE KIND—CHAUDRON PROCESS.

The expense of sinking shafts by the system we have described is always lower than by the ordinary method of mining in all cases

where the use of at least two pumps of a diameter of 0.55 meter would be needed in the latter case, but it varies according to the nature of the ground. The duration of the operation is considerably prolonged whenever the soil is of a very crumbling or running nature, or in cases where it is exceptionally hard and tenacious.

Under the best conditions, the cost of sinking and tubbing a shaft by the Chaudron process may be set down as 2500 francs (about $500 gold) per meter on an average for a diameter of 12 feet, and has never in the worst cases exceeded 4000 francs (about $800 gold) as a maximum. For a width of 15 feet we may safely estimate on a minimum cost of 4000 francs ($800 gold) per meter, and not to exceed 6000 francs per meter ($1200 gold) as a maximum.

The occurrence of shifting sand or gravel, or of loose clay or quicksand, is always a cause of supplementary expenditure, as it may render the use of a certain amount of protective or temple-tubbing indispensable.

We furnish here a few examples of the actual cost of sinking shafts by the Chaudron process, from careful accounts kept by the contractors, which will suffice in a general way for the appreciation of the details of such undertakings.

Cost of the Sinking of the Shaft of Sainte Marie at Péronnes.

	Francs.	Francs.
A.—First Cost. Comprising:		
1. Widening shaft to a diameter of 4 meters, to a depth of 10 meters; 2 Establishment of a lateral excavation for reception of trepan; 3. Construction of a shed and erection of engines within it; 4. Erection of a boring house,		3,559.18
Labor:		
Bricks, lime, sand,	588 25	
Lumber,	3,957.68	
Various materials,	493.71	
		5,039.64
Cost of repairs of machines and tools,		1,492.25
Total,		10,091 07
B.—Sinking of Shaft:		
Salaries of all kinds,		12,173 74
Coal (4632 hectoliters),	4,325.25	
Grease and oil,	545 48	
Wood,	458.30	
Steel, iron, and metal,	474.94	
Various objects,	603.69	
		6,407.66
Total,		18,581.40

C.—TUBBING:

1. Cost of tubbing; 32 rings of cast iron, including the moss-box, weighing altogether 86,682 kilograms,	18,476.06	
750 bolts, weighing 1020 kilograms,	612 00	
31 rolls of sheet-lead for the joints,	546 40	
Moss-box,	466.20	
		20,100.66
2 Cost of concrete outer lining:		
Cement,	1,536 00	
Trap,	879 40	
Lime,	405.00	
Sand,	358.15	3,178.55
3. Various expenses:		
Carriage and lowering of the tubbing,	2,398 60	
Cementing,	1,516.03	3,914.63
Consumption:		
Wood,	353 75	
Coal,	970 60	
Steel, iron, and metal,	120.92	
Oil and grease,	112.16	
Rope,	588 60	
Various expenses,	445.58	2,591.61
Total,		29,785.45

The summary of the above would be:

	Francs
A. First cost of installation,	10,091.07
B. Sinking of shaft,	18,581.40
C Tubbing complete,	29,785 45
D. Sinking fund for wear and tear of tools,	6,000.00
Total,	64,457.95

This shaft had a depth of 108 meters, and was tubbed for a height of 62 meters exclusive of the moss-box.

COST OF SINKING SHAFTS NO 1 AND NO 2 OF L'HÔPITAL.

	Shaft No. 1.	Shaft No 2		Shaft No. 1.	Shaft No. 2.
	Francs	Francs.		Francs.	Francs.
I. COST OF INSTALLATION.			Netting for moss, . .	21 10	25 00
			Moss, ...	34 80	40 00
Buildings, ...	28,302 65	46,702 47	Wood, . .	345 00	1,461 05
Machines and tools, .	37,326 91	57,869 30	Labor cost of lowering,	3,447 82	8,456 44
			Coal, ...	1,375 25	3,357 55
II. SINKING PROPER.			Oil and grease, . . .	258 03	754 40
Salaries, ...	55,039 81	72,738 54	Cost of transportation and others, . . .	4,566 80	7,544.79
Coal, ...	12,513 71	27,524 60			
Oil and grease, . .	2,381 11	4,720 49	IV. CONCRETING.		
Ropes and cables worn out, ...	2,987.20	3,602 35			
Iron, steel, tool repairs,	12,530 90	14,469 83	Salaries, ...	4,440 43	
Transportation and sundries, ...	7,560 66	16,603,50	Cement, trap, and lime,	4,311 83	
			Coal, ...	599 11	15,000.00
III. TUBBING.			Oil and grease, . . .	178 05	
Cost of iron tubes, . .	66,426 94	138,494 34	Various items and transportation, . .	2,281.78	
Lead for joints, . . .	1,665 60	3,601 10			
Bolts, ...	1,340 99	4,915 20	V. FOUNDATIONS.	6,009 48	10,000.00
Red lead, ...	95.20	126 40			
Tar, ...	. . . .	443 80	Total, . . .	256,041.16	440,451 15

SUMMARY.

	Shaft No 1.	Shaft No 2		Shaft No. 1.	Shaft No 2.
	Francs.	Francs.		Francs	Francs.
Buildings, machines, and tools, ...	65,629 56	104,571.77	Concrete, ...	11,811 20	15,000.00
			Basement, ...	6,009.48	10,000 00
Sinking shaft, . . .	93,013 39	141,659.31			
Tubbing shaft, . . .	79,577.53	169,220 07	Total, . . .	256,041 16	440 451,15

These two shafts were bored to a depth of 492 feet, and were furnished with 449 feet of cast-iron tubbing. The weight of the tubbing in shaft No. 1 reached 258 tons; in shaft No. 2, 635 tons.

APPENDIX III.

LIST OF SHAFTS SUNK AND TUBBED BY THE CHAUDRON PROCESS.

Location.	Name.	Height of temple tubbing in feet.	Diameter in feet.	Sinking Begun.	Sinking Ended.	No. of pits	Height of tubbing in feet	Total depth in feet.
France, Pas de Calais, . .	Liévin, . . .	. .	12	1872	1875	3	248	290
" " . .	Meurchin, . .	100	10	1872	1875	2	298	298
" " . .	Vendin, . .	45	12	1873	1875	1	330	365
" " . .	Bruay, . . .	45	12	1874	1876	2	295	400
" " . .	Marles, . . .	18	12	1873	1876	2	285	400
" Nord, ...	Douchy, . .	60	12	1872	1874	1	115	115
" "	Aniche, . . .	120	10	1873	1875	1	291	298
" "	Crespin, . .	60	12	1874	1875	1	350	369
" "	Escarpelle, . .	60	10	1868	1870	2	310	338
" "	" . .	80	12	1876	in prog.	2	312	. .
" "	Marly, . . .	. .	12	1876	in prog	1	.	. .
" Landes, ...	Dax, ...	. .	7	1875	in prog	1	. .	. .
Belgium, ...	Péronnes, . .	25	12	1862	{1863 1875	4	195	236
"	Maurage, . .	.	12	1870	1872	2	518	626
"	Ciply, . . .	. .	12	1873	1875	2	231	285
"	Ghlin, . .	70	12	1875	in prog.	2	. .	760
"	Bracquegnies,	. .	13	1876	in prog	2	. .	721
Great Britain (Staffordshire),	Cannock, . .	.	15	1876	in prog	2	. .	394
Germany, Alsace-Lorraine,	L'Hôpital, .	. .	11	1863	1867	2	449	492
" "	" . .	130	12	1875	in prog.	3	. .	520
" Westphalia, .	Dalbusch, . .	.	12	1852	1853	1	302	302
" " . .	" . .	. .	12	1865	1866	2	302	302
" " . .	" . .	. .	12	1872	1873	2	302	302

BORACIC ACID IN LAKE SUPERIOR IRON ORES.

BY PROF. T. EGLESTON, PH.D., SCHOOL OF MINES, COLUMBIA COLLEGE, NEW YORK CITY.

DURING the last winter we have been actively engaged in the School of Mines in search for boracic acid. This has been owing to the fact that Mr. M. W. Iles, assistant in the qualitative laboratory, has discovered a test for that substance which makes its discovery exceedingly simple instead of being, as previously, very difficult. It consists in powdering the mineral, calcining it, then moistening it with sulphuric acid, and heating on a platinum wire until the sulphuric acid is expelled. It is then moistened with glycerin and made to take fire. If boracic acid is present it infallibly gives a green flame. It is not at all surprising, under such circumstances, the test being so easy, that boracic acid has been found by the students in a great many cases where its presence was not previously suspected, and in some where its detection was previously too difficult to warrant looking for it. We were not prepared, however, for its discovery in Lake Superior iron ores, and were disposed at first to think that a mistake had been made. After, however, it had been frequently reported in these ores it was considered worth while

to look for it, and having found it to ascertain in what condition it was.

It was then, to my very great surprise, discovered that certain Lake Superior ores are so completely filled with a borate that it is not possible to find the smallest piece which does not contain white specks, which have proved to be a borate of lime and magnesia, which is probably a new mineral, as no borate corresponding to it is described. Sufficient quantities of it have been detached from the ore, entirely free from iron, and Mr. Iles will probably make the analysis and publish the results before the next meeting of the Institute.

I consider this result most surprising considering the fact that so many thousand specimens of Lake Superior ores have passed through the hands of chemists. I think it is more than likely, as the boracic acid is present in such quantities in the ore, that we shall find some boron in the iron. If this is so, its presence will satisfactorily explain some of the peculiarities of the Lake Superior iron. I do not think it very likely that the iron will contain very much boron, for the probability is, since the borate of lime and magnesia is exceedingly fusible, that the larger part of it will go into the slag; but it is more than likely that some of it will be found with the silicon. Exactly what its effect is cannot be stated before an investigation is made; but it is probable that we shall hereafter be obliged to look for boron in iron, a substance which has heretofore been unsuspected, and it certainly will be an exceedingly interesting matter to ascertain by direct experiment what its effects upon the iron are, since so little is known about it that most authors do not mention it as one of the possible impurities of iron.

A STUDY OF THE SPECULAR AND MAGNETIC IRON ORES OF THE NEW RED SANDSTONE IN YORK COUNTY, PA.

BY PROF. PERSIFOR FRAZER, JR., PHILADELPHIA.

IN his "Final Report," Vol. II, part second, p. 763, Prof. Rogers sums up the metalliferous veins of the mesozoic sandstone by remarking that these are not associated with dykes or trap-rock, but are independent metalliferous injections. But singularly enough, in enumerating the different kinds of ores, no mention is made of

the iron ores which are now under consideration, although some of those in the vicinity of Dillsburg have been wrought for a very long period. The ores of Cornwall and of the Jones Mine are referred to the older formations, but these are of an apparently different character. The Dillsburg ores are all more or less soft lumps of specular and micaceous ore carried in clay. Their general appearance is dark, dirty-green, with streaks of black and glistening pulverulent ore. They are very irregularly deposited, but almost or quite without exception are found between the plates of rock which make up this portion of the mesozoic sandstone. An ideal section north from the Grove mine will reveal this. The region is very much covered with disintegrated rocks, as clay or sand, and very few surface exposures are to be found in the neighborhood of Dillsburg. The rocks which have best resisted the weather have been the traps, and, *as a general rule* in this region, their dip corresponds to that of the beds between which they were poured out. Next to the trap (and sometimes even before it), in capacity to resist the disintegrating action of the water and atmosphere, comes the altered and indurated mud rocks and argillaceous sandstones which frequently form the foot or hanging wall, or both, of these veins. Commencing our line at the Grove slope, and getting the dips by aid of trap ore beds, etc., where no better means offer, or from the slope itself (an equally good method, since the large ore deposits are generally along bed-plates, and the miner is pretty sure to keep on the dip of the bed) we find their average to be N. 10° E.—24°.

For about 2200 feet north no mines are observable, when there occurs on the projection the Bell slope, in which the hanging and foot walls dip about N. 10° E.—20°.

Supposing these two mines to be in two different veins of ore, and to be continuous, their horizons in the measures would be at a (perpendicular) distance apart of 750 feet.

Again, for 1400 feet northwards no ore mine is projected, and at a little over this distance occurs the old excavation (the first in this vicinity to be exploited), in which Mr. Underwood has recently sunk a new shaft.

There is an excavation between this and Bell's slope, but no accurate information in regard to it was obtained. The pit is about 15 feet deep, and the shaft is sunk from its lowest point for 25 feet, when a body of ore is said to have been struck. If so, and the dip of the rocks is here similar to that in the slope, the outcrop of the

vein ought to be seen crossing the neck of the narrow southern prolongation of the pit about 80 feet south.

About 150 feet further north on the line occurs the projection of the ore in Underwood's slope (which is probably the same bed as that struck in Logan's shaft). The inclosing rocks and the slope dip about 28° due north, and the latter extends 290 feet below day, and proves the ore for that distance. 500 feet a little east of north of the mouth of Underwood's slope, on ground 30 feet below it, the Logan shaft has been sunk, which reached the ore at 50 feet, from which point a slope was begun and extended downwards, at an angle of 28° (conforming to the dip of the measures), 80 feet.

Projecting this vein upwards, it is found to intersect the surface on the same horizontal plane with the mouth of Underwood's slope, at a point 170 feet south of the mouth of the shaft. Connecting this point with the point of outcrop of the Underwood vein by a supposititious outcrop line, it is found to run east 80° south, and the direction of dip of the vein to which it corresponds is north 8° east.

The coincidence of this direction with that of the Grove and Bell banks (N. 10° E.) is too striking to be overlooked, and leads to the conclusion that the bedding of the rocks between these points is comparatively regular, and the strata for half a mile south of the Underwood-Logan are undisturbed by faults. 160 feet northeast of the Underwood slope is an excavation 140 feet in length northeast, and about 35 feet broad in its broadest part.

The Wrightsville Company is said to have wrought this bank to a very considerable depth, and to have had 18 feet of ore in the bottom of it. It was not satisfactorily ascertained at what depth this ore occurred, and the settlement of this doubt has an important bearing on the question of the number of the ore veins here represented. 100 feet north of this latter opening (now a pond) is the southern margin of a very large excavation, 100 feet long, and 125 feet north and south.

Near the southeastern corner of this pond, and high upon the bank, is the site of a former mouth of a slope. A little west of north of it (in the northwestern angle) is the place of a former bore-hole (No. 5), the record of which has been already given, and 50 feet north of this bore-hole is a stake, said to have been vertically over the end of the slope. This stake bears north 3° 30′ west of the mouth of the slope, and if these data may be depended upon, indicates an alteration in the direction of the dip from that observed at

the Grove and Bell slopes of 11° 30′ to the westward. 125 feet northwest of bore-hole No. 5 are two openings; the first an open cut long since abandoned, and a little southwest of it the mouth of a slope which was said to have been formerly driven 158 feet, at an angle of 18°, and to have been left in 4 feet of ore at a vertical depth beneath the surface of 60 feet.

(If the 18°-slope was maintained, the vertical depth of the bottom of the slope would be 48 feet.)

This ore, if carried down at the same angle of 18°, would coincide closely with the bed of ore said to have been struck in bore-hole No. 4, at a depth of 74 feet and 2 inches. The thickness of the bed is reported to be 7.25 feet, which (allowing for its obliquity to the bore-hole) would indicate that the ore has widened at that depth to 6.8 feet—a variation by no means uncommon. It may be assumed, therefore, that this ore has been proved for a distance of 260 feet on its slope.

150 feet from bore-hole No. 4 occurs the long cut of McCormick & Co. This cut has been opened 400 feet west 20° north along the outcrop of rock ore, and two slopes have been driven downwards.

Both the direction and the strength of the dip of this deposit are suddenly altered, the former being north 20° west, and the latter 45°.

A slope of 18° was started from the cut and carried 30 feet, when a wall of hard trap (dolerite) was encountered, apparently cutting off the ore. Another slope was begun at an angle of 45°, and after proceeding a short distance the trap was again encountered and penetrated, and the ore beneath it was observed to be continuous with the normal dip of the country rock, or about 18°.

The following data were taken from a copy of the records in possession of McCormick & Co., which appeared on a sketch-map made by Mr. R. H. Sanders to illustrate a private report on this region, made by Mr. Franklin Platt:

The record of bore-hole No. 1 showed:

Surface.	Feet.
1. Clay,	4
2. Sandstone,	8
3. Clay,	2
4. Bastard (?) limestone,	9 5
5. Sandstone,	9.5
6. Trap,	9
7. Unknown (about),	20
8. Brown sandstone,	12
9. Iron ore,	6
10. Sandstone,	4
11. Lean iron ore,	4

About 50 feet from the long cut, and towards the western end, bore-hole No. 3 was sunk. It showed:

Surface.	Feet.
1. Clay,	4
2. White sandstone,	6
3. Red "	7
4. Trap,	17 5
5 Black and green sandstone,	4
6. Brown sandstone,	1
7. Green "	8
8. White "	1 5

Bore-hole No. 4 is situated about 150 feet east of south of the eastern extremity of the long cut. Its record was:

Surface.	Feet.
1. Clay,	2
2. Gray sandstone,	8
3. Red "	7
4. Unknown,	10
5. White sandstone,	7.5
6. Greenish-white sandstone,	6 16
7. White sandstone,	6.41
8. Green "	2.83
9. Red "	0 5
10. Black (?) trap,	16.08
11. White (?) "	6.66
12. Ore,'.	1.5
13. White sandstone,	22 25
14. Green "	13.16
15. Red and white sandstone,	6.00

Bore-hole No. 5, sunk in the old bank of McCormick & Co., showed:

Surface.	Feet.
1. Soil,	8.84
2. Green sandstone,	0.17
3. Iron ore,	0.17
4. Gray sandstone,	4.50
5. White "	6.17
6. Reddish-green sandstone,	12 08
7. Black (?) trap,	23 07
8. Gray sandstone,	3.25
9. Iron ore,	3 25
10. White sandstone,	5.00
11. Iron ore,	1.33
12. White sandstone,	11.00
13. Limestone and flint,	6.00
14. Limestone and fire-clay,	10.00

Surface.	Feet.
15. Red sandstone,	14 00
16. Green "	4 00
17. White "	9.00
18. Green "	3.00
19. Iron ore,	2 00
20 Sandstone,	2 00
21. Sandstone and ore,	3 00
22. Limestone and flint,	6 50
23. Ore and sandstone,	0.50
24. Green sandstone,	5 00
25. White "	5 00
26. Green "	6 00
27. White "	1.00
28. Gray trap,	2 00
29. White sandstone,	2 00
30. Limestone,	3.00
31. Gray sandstone,	4.50
32. Red "	4 00
33. White "	4 00
34. Red "	1.00
35. White "	4.00
36. Red "	3.00
37. White, "	4 50

From the records of bore-holes 1, 3, and 4, and the light thrown upon the structure by the slopes from this cut, this plate of traps appears to strike northeastwardly and to dip gently southeast, conforming no doubt to some plane or planes of cleavage which are frequently met with throughout the entire area of the New Red. This dyke would cross the axis of the open cut at or near its southwestern extremity, and this is possibly the reason that an exploitation pit sunk some 50 feet from the latter point discovers the ore "pinched out."

From the records of bore-holes Nos. 1, 3, and 4, a trap dyke is recorded at a depth of 33 feet, 17 feet, and 51 feet from the surface respectively. This dyke is represented as at least 9 feet thick in No. 1 (with a possible extension downwards of 42 feet marked "unknown"), 17½ feet in No. 3, and 16 feet in No. 4.

The positions of bore-holes Nos. 1, 3, 4, and 5 can be observed upon the map of this property on Plate II. It appears that in No. 1 a mass of trap was struck at 33 feet from the surface, and entered for about 9 feet. For the next 20 feet no record of the boring was kept. In No. 3 the trap was struck at 17 feet below the surface, and entirely penetrated the thickness, proving to be 17½ feet. In No. 4 a trap was encountered at 51 feet below the surface, and proved

to be 16 feet 1 inch thick. In No. 5 a trap was met with 23 feet below the point of starting at the bottom of the bank, or 18 feet below the surface, and is said to be 23 feet 1 inch thick. There is nothing inconsistent with the idea that these occurrences of trap represent points on the upper surface of a large dyke because of these records of varying thickness. Such differences will frequently arise from the close resemblance which the altered rock in contact with the dyke bears to the latter, while the exhibition of plates of trap between the regular beds and in the planes of cleavage and jointing is not rare in the New Red Sandstone. The ascertained thickness of the plate in bore-hole No. 3 agrees very well with that in No. 4.

The thickness in No. 1 is not given. Independently of the fact that much is called "trap" which is nothing but indurated sediment, the expansion of the bed (if it be the same) to 23 feet in bore-hole No. 5 is not at all anomalous. By assuming, then, that the upper surface of this same bed of trap was met with in bore-holes Nos. 1, 3, and 4, at 33 feet, 17 feet, and 61 feet* below a common plane (the 650 feet contour),† we have the data for calculating the inclination and direction of dip of the bed and the line of the strike on this plane. The latter proves to be N. 23° 30′ W. It was obtained: 1st, by calculating the point at which a straight line, passing 33 feet below the mouth of No. 1 and 17 feet below the mouth of No. 3, would intersect the horizontal plane in which the starting-points of Nos. 1 and 3 both lie; 2d, calculating similarly the point on this plane at which a straight line 51 feet below the surface at 4 and 17 feet below the surface at 3 would emerge; 3d, establishing similarly the intersection of the datum plane by a straight line passing 51 feet below 4 and 33 feet below 1. It is evident that if these three points thus projected fall into the same straight line, the inference is very strong that the surfaces of trap from which they were independently calculated are parts of one large surface or approximate plane. This they very nearly do. The deviation of the last-named point is hardly to be avoided, owing to the acuteness of the angles made by the lines joining the bore-holes.

In Diagram I, Plate II, the letters I, N, M, and V are chosen to

* 10 feet must be added to the recorded 51 feet below the surface, because the datum plane of No. 4 (the surface at that point) is 10 feet lower than the surface at Nos. 1 and 3.

† 650 feet above high tide at Philadelphia.

represent the bore-holes I, III, IV, and V respectively, the number of downward strokes in each of the first three letters corresponding to the number of the corresponding bore-hole.

Selecting bore-holes Nos. 1 and 3 (IN), we have (Diagram II, Figs. 1 and 3) the distance between them IN = 116 feet.

II′ = depth from the surface to trap at No. 1 = 33 feet.

NJ = depth from the surface to trap at No. 3 = 17 feet.

To find the length of the line AI, or the distance from the mouth of the bore-hole No. 1, at which a line passing through it and 3 would intersect the outcrop line, through I′ draw a line parallel to AI, produce the vertical NJ till it intersect this line A′ I′ at J′.

Let $x = \mathrm{AI}$

Let the angle $\mathrm{AI'J'} = \alpha$

Then $\dfrac{\mathrm{JJ'}}{\mathrm{I'J'}} = \dfrac{\mathrm{II'}-\mathrm{NJ}}{\mathrm{IN}} = \dfrac{16}{116} = 0.13791 = \tan \alpha$

$\alpha = 7° \ 51$

$x = 61 \cot \alpha = 239.35$ feet.

In the triangle MBM′ (Fig. 2),

Let $x = \mathrm{MB}$ $\quad$ $\mathrm{MN} = 412$ feet.

Let $\beta = \mathrm{MBM'}$ $\quad$ $\mathrm{MM'} = 61$ feet.

$\mathrm{NJ} = 17$ feet.

$$\tan \beta = \frac{44}{412} = 0.10679 = \tan 6° \ 6'$$

$$x = 61 \cot \beta = 570.791.$$

In the triangle VCV′ (Fig. 3),

Let $x = \mathrm{VC}$ $\quad$ $\mathrm{VN} = 602$ feet.

Let $\gamma = \mathrm{VCV'}$ $\quad$ $\mathrm{VV'} = 58$ feet.

$\mathrm{NJ} = 17$ feet.

$$\text{Then } \tan \gamma = \frac{41}{602} = 0.068106 = \tan 3° \ 54'$$

$$x = 58 \cot y = 850.77 \text{ feet.}$$

In the triangle MDM′ (Fig. 4),

Let $x = \mathrm{MD}$ $\quad$ $\mathrm{MI} = 390 \ 5.$

Let $\delta = \mathrm{MDM'}$ $\quad$ $\mathrm{MM'} = 61.$

$\mathrm{II'} = 33.$

$$\text{Then } \tan \delta = \frac{28}{390.5} = 0.071702 = 4° \ 6'$$

$$x = 61 \cot \alpha = 850{,}993 \text{ feet.}$$

If we plot these points accurately on the map (Diagram 1, Plate II), and lay off distances corresponding to the calculated lengths of

the several perpendiculars of the three triangles, viz.: IAI′, MBM′, MDM′, and VCV′, it will be found that the three points A, B, and D fall very nearly in a straight line. But owing to the greater angle which IA and MB make with the outcrop line, the points calculated from them are more reliable than the points calculated from MDM′, in which the angles MDM′ and MM′D are very small, so that a very slight error in the experimental data would change the resulting side MD greatly. Neglecting the point D for the moment, and drawing the line through AB, it is observed that it passes *within five feet* of the point as determined by MDM′. In view of the fact that nature does not pour out trap or arrange the layers of rock in absolute geometrical planes, this deviation of 5 feet from the line due to an excess of 15 feet in a length of 841 feet (1.7 p. c.) is inconsiderable.

In the triangle VCV′ the conditions are yet more unfavorable for accurately determining the position C. The angle between AB and VC is but 13° 25′, and the angle VV′C is 86° 06′, while the rough statements in regard to the bore-hole No. 5 render it very difficult to locate the point V′ with exactitude. Of course in triangles when hypothenuse and perpendicular make so small an angle, a very slight error in angle will produce a very considerable one in the horizontal distances. Owing to these facts (and very probably also to local irregularities in the bed) the point C falls 50 feet from the line and 212 feet short of its proper intersection with the latter in a line of 841 feet, showing an error of 25 p. c.

On the other hand, the close agreement of the other more favorably constructed triangles furnishes a strong support to the above supposition as to its location.

The dip of the bed of trap as calculated by assuming this line of N. 23° 30′ W. as the correct outcrop on a plane 650 feet above high tide in Philadelphia, is given in the following tables:

Dip calculated from No. 1, ...	E. 22° 30′ N. —9° 29′.
" " " No. 3, ...	E. 23° 30′ N. —9° 39′.
" " " No. 4, ...	E. 23° 30′ N. —8° 01′.
" " " No. 5, ...	E. 23° 30′ N. —9° 39′.
Dip calculated, assuming the trap in Logan's shaft to be the same as that in the above bore-holes, ...	2° 51′.

It is evident from this that there are two plates of trap occurring here at a perpendicular distance from each other of about 15 to 20 feet. The analogy which this structure presents to that of the Corn-

wall mines will be reserved for a future occasion. Continuing this assumption as to the identity of these scattered occurrences of trap in one bed, we find that trap should have been met with in the southwest slope of McCormick & Co.'s long cut at 30 feet below the surface, and in the northeast slope of the same cut at about 54 feet below the surface. The first of these statements accords well with the facts, while there are none reliable with which to compare the second.

These slight discrepancies in the calculated dip of the trap are of no importance, and are far within the limits of accuracy of observation.

This outflow of trap probably followed one or more of the planes of cleavage of which these rocks are full. If this interpretation be correct, the upper surface of the lower dyke would emerge on the surface of the ground midway between the southwest end of the long cut and the exploitation pit still further to the south, where the ore was reported to have "pinched out," and if we assume as the thickness of the bed 17 feet and 9° 29′ as the dip, the breadth of the outcrop would be 60 feet. This would embrace the entire area of the pit. It is not clear how far this outcrop extended S. 23° 30′ E., nor whether its breadth was maintained. If persistent it would pass between Underwood's slope and the old abandoned excavation next northeast of it, and would thus interpose a wall of igneous matter between the Underwood, Smyser, and Grove banks from those of Mr. McCormick, including the Logan shaft with Bell's and Price's.

There is nothing in these observations of the thickness inconsistent with the view that these are made on the same dyke, and the probability that Nos. 3 and 4 are so is very strong. Assuming this to be the case, and calculating the inclination and direction of the upper surface of this dyke from the depth beneath, a common datum plane of its appearance in the three bore-holes, we find that its dip is E. 23° 30′, N.—9° to 12°, and projecting its outcrop on the surface it is found to pass through the small excavation where no ore was found southwest of the main cut.

It is perhaps owing to this circumstance that the outcrop of the Logan ore is not seen to connect the Underwood slope with some point 100 feet or more south of the Logan shaft; for if this dyke be continuous in a cleavage plane or other joint in a direction S. 23° 39′ E. from its supposed outcrop at the McCormick cut, it would cut

off that portion of the vein between the shaft mouth and the natural line of outcrop of the Logan ore by cutting the vein a short distance west of the former. It follows also that if continuous under the surface, and with the observed gentle dip of 9° 20′, it will intersect the Logan slope at a point far below where the trap was observed, viz., at 12 feet below the 340 feet contour line. The record of this Logan shaft is not at hand, but specimens of dolerite were obtained from it and studied under the microscope, which in mineral constitution (*i. e.*, number and distribution of apatite crystals, etc.) agreed very closely with similar specimens from the Mumper or McCormick cut examined in the same way.

This renders it likely that the outflow of trap along the two planes just mentioned, viz., on the Logan shaft and in the Underwood and McCormick mines, was contemporaneous, or at least had the same origin. The whole deposit of ore of this part, the Dillsburg region, seems to be reducible to—1st. Deposit of ferruginous matter along the bed planes of the rocks of the New Red Sandstone in an irregular manner. 2d. The presence of one (and probably more) large dykes following planes of cleavage or jointage, and striking northwest and southeast with a gentle dip. 3d. The alteration of mud rocks and slates to "traps" (?) of induration, and of the more or less hydrated iron oxides to magnetic and specular ores. The greenish color of these soft ores, when not derived from the oxidation of copper, is due to the commingling of the lower chlorite and hydro-mica slates with the iron ore, and indicates possibly that at least some of this ore was obtained from its depositories in the older slates. But that, even if entirely derived from this source, they have been made up in the course of their transfer to the beds of the New Red Sandstone appears to be beyond question.

The observations of Prof. Lesley, Dr. Hunt, and others, of the great Cornwall iron ore deposit, agree in ascribing its existence to several protecting plates of hard trap, which have resisted the erosion by which the soft ore, if not thus protected, would probably have been entirely destroyed. It is not quite certain how much of the magnetic particles with which these ores are mixed may have come from the trap itself. It is likely that much is to be ascribed to this source; but however that may be, it cannot but be of the greatest significance that the two plates of trap which occur near these mines inclose or cover the greater number of the producing deposits.

From an inspection of the ground it appears that the new King

bank (which seems to lie outside of this protecting influence) has a dyke of its own on the eastern (*upper*) side.

The points in favor of the above structure are as follows:

1. The existence of trap in bore-holes Nos. 1, 3, 4, and 5, and in McCormick's cut, Underwood's slope, and Smyser's bank, at points which are very approximately in one plane.

2. The non-occurrence of trap in bore-hole No. 2 (though so near to Nos. 1 and 3), because No. 2 is located just below the edge of the lowermost of these plates.

3. The trap in Logan's shaft is corroborated by the shape of the contours north of the long cut. Its supposititious outcrop closely coincides with the nose of a small hill, as it necessarily would do, owing to its superior resistance to erosion.

4. The practically similar thicknesses of the trap as measured in bore-holes 3 and 4.

5. The cutting out of the ore in the pit at the southwest end of the long cut.

6. The identity of the mineralogical constitution of the traps of Logan's shaft and the long cut viewed under the microscope.

If these facts be accepted as conclusive as to the structure, the idea of faults bringing up the same bed of ore successively to the surface must be abandoned, unless it be supposed that the dislocations took place before the injection of the molten rock, in which case the extension of the latter on cleavage planes over so wide an area is rendered in the highest degree improbable, because in order that a plate of trap should be thus continuous when poured out through a cleavage plane crossing several faults, we would have to suppose that each fault had brought up from below a cleavage plane and attached it accurately to one above, so that the two had equal inclination and formed one plane.

The supposed outcrop of the trap has been drawn in the map, Plate II, with reference to the 5-feet contours, on the assumption that tangent of 9° 29′ (the assumed average dip of the trap), or 0.167043, is $\frac{1}{6}$; or, in other words, that the ratio of the vertical distance apart of the contour lines is to the horizontal distance apart of the projections of the trap at those contours as 1 is to 6 (more accurately it is 1:5.98).

A STUDY OF THE IGNEOUS ROCKS.

BY PROF. PERSIFOR FRAZER, JR., PHILADELPHIA.

I DESIRE to say that, owing to the number of papers which have been more or less crowded at this session of the Institute, and the fact that, as one of the Local Committee, I have the distinguished honor to feel somewhat like one of the hosts, I should not tax the patience of members at this late hour, but would have my paper read by title were it in any way possible to do this. But the task I have set myself this evening is to present to the eyes of the members of the Institute certain objects which have occupied more or less of my time during the last eighteen months or two years. The objects I allude to are some of the igneous rocks of this country, which, until quite recently, have been less understood than any others.

It will be well known to some of the members that some of the cooled lavas of a previous age of our planet, when not directly coarsely crystalline and granular, were considered and spoken of as "natural glasses," or perfectly uncrystalline, vitreous, or hyaline masses of matter.

Among the first results of the use of the microscope was the dispersion of this fallacy. Sir David Brewster, Mr. H. C. Sorby, and William Nichol (the discoverer of the celebrated calcite prism, which bears his name), had, with greater or less success, examined sections of various rocks and minerals, both by transmitted and reflected light, and also in the form of powder. But, until the genius of Vogelsang undertook the subject, these investigations had no permanent value, nor did they constitute an independent line of mineralogical and geological research. Since the close of his labors, by Vogelsang's premature and much-lamented death, the subject has been made one of renewed interest by his brother-in-law, Ferdinand Zirkel, as well as by Rosenbusch, Tschermak, and many others abroad, and at home by the commencement of a systematic study of the traps of Connecticut by Messrs. E. D. Dana and G. W. Hawes, of New Haven, and by the splendid set of described sections of the traps of the West which have been furnished by Zirkel to illustrate Clarence King's report.

I had the honor of presenting a large number of thin sections of our traps at the Washington meeting, for the inspection of the members, with the aid of a table microscope belonging to the Smithsonian Institution. Here I propose to project these sections upon the

screen so that all can see them alike. Before I do this, however, I will introduce a few words to inform those who have never paid any attention to this subject how these slides must be prepared. As thin a fragment as possible of the rock is chipped off with the hammer. One side of this is rubbed down on a cast-iron plate with emery and water, as nearly as possible to a perfectly smooth and level plane. (This is not such an easy mattter as it might seem.) This being done, the surface is washed carefully, so as to exclude every particle of dirt, when, to guard against the possibility of small cavities filled with powder, the tongue is called into requisition to discover them. When perfectly clean, the specimen is warmed to drive off all moisture, and then is attached to the holding glass, by pressing it against Canada balsam which has been boiled half a minute or more, and is still soft and adhering to the glass. If properly treated the balsam will harden in five or ten minutes.

The holding-glasses which I prefer are strips of mirror plate-glass, $\frac{1}{4}$ inch thick, and ground on one side. This latter precaution, to which I was driven by the sacrifice of many fine specimens, appears to be a very needful one, and if attended to will save much vexation and disappointment. The thick glass is then taken in the fingers and the other side of the rock or mineral fragment is rubbed on the plate until the required thinness is reached, a point which is determined by the equal transparency of the section in all its parts. The portions of balsam outside of the outline of the section are then cut away with a penknife. A clean thin glass slide is warmed and provided with a small drop of balsam, the holding-glass is then gently warmed and inclined over it, and, if necessary, the section is eased off by the aid of a penknife or other object. The thin slide is again warmed until the drop of hardened balsam distributes itself over the surface and flows freely with the section. If the latter is not already completely immersed in balsam, it is either gently pressed beneath the surface or parts of the balsam are placed over it.

A thin cover-glass is then laid on the glass, so that it is in an *inclined position*, one end projecting into the air and over the section. By warming the slide gently, the cover will then descend evenly, allowing all the air to escape. A little practice is necessary to get the object in the middle of the glass slide and well trimmed.

There is no means of determining the necessary thickness of a section, except for a particular case. In no instance should the section be so thick as to cause the cover-glass to break when the two ends are pressed over it against the glass slide. On the other hand,

minerals of characteristic color become sometimes colorless when sliced too finely. The thickness of those which it is my intention to show to-night varies from $\frac{1}{150}$th to $\frac{1}{500}$th of an inch.

[A number of dolerites from Adams and York Counties, Pa., were here thrown upon the screen, and resolved into their constituents, labradorite, pyroxene, and magnetite. Biotite and apatite were recognized by their forms and their effect upon polarized light. A rare trap, from near the western edge of the Mesozoic Red Sandstone in York County, was shown to consist largely of pegmatolite, with much hornblende. The coarse and fine-grained dolerites were compared. Other rocks, belonging to Sub-Silurian (Huronian (?)) age, such as the orthofelsite-porphyry of the South Mountain, near Mont Alto, and a quartzite, of which this mountain is largely composed, were then projected, and attention was called to the fact that in the latter specimen some of the constituent particles of silica appeared to be angular and some were rounded.]

AN ANALYSIS OF A SPECIMEN OF SILVER-GRAY OR GLAZY IRON.

BY EDWARD HART, LAFAYETTE COLLEGE, EASTON, PA.

THE specimen of glazy iron used for analysis was highly characteristic in appearance. It was made at one of the furnaces of the Glendon Iron Works, working a light burden of ore with a highly silicious cinder. There are very few records of analyses of this variety of iron. I have been able to find but the two given by Bell, and I add these to my analysis for comparison.

		Bell. 1.	Bell. 2.
Iron,	89 47*	88.18	90.70
Carbon, combined,	0.00	0 79	0.71
Graphite,	2.88	2.59	2 68
Silicon,	5.47	5 13	5.13
Manganese,	1.54	0 77	0 56
Sulphur,	0.04	0.17	0 23
Phosphorus,	0 60	1.12	1 12
Titanium,	——	0.26	0 18
Calcium,	0 00	0.22	0 20
Magnesium,	0.00	0 06	0 03
	100.00	99 29	101.54

* By difference.

The cinder accompanying this iron had 47.50 per cent. of silica. The graphite was determined by boiling a sample of the borings with hydrochloric acid for an hour, filtering through asbestos, and washing successively with water, potassium hydrate, water, ether, alcohol and water. The total carbon was determined by dissolving the iron in neutral cupric chloride, dissolving the precipitated copper in hydrochloric acid, filtering through asbestos, and washing with water. After drying, the carbon residues were burned in oxygen in a porcelain tube. Duplicate determinations of the graphite gave 2.87 and 2.89 per cent., and of the total carbon 2.89 and 2.87 per cent., showing that all the carbon was in the graphitic or uncombined form. Dr. Drown has shown (Transactions of the Institute, Vol. III, p. 41) that treatment by boiling with hydrochloric acid (sp. gr. 1.12) is the method most favorable for the elimination of combined carbon, when present.

The silicon was determined by treatment with nitric acid, evaporating to dryness, heating for some hours in an air-bath at a temperature of 120° C., dissolving in hydrochloric acid, filtering, burning off the graphite, and fusing the impure silicious residue with mixed alkaline carbonates. The sulphur was determined by absorbing the sulphuretted hydrogen evolved by the action of hydrochloric acid by potassium permanganate, as recommended by Dr. Drown (Transactions, Vol. II, p. 224). The phosphorus was determined by ammonium molybdate and subsequent precipitation by magnesium mixture.

I was unable to detect any calcium or magnesium in the iron. The sample had a specific gravity, at 15° C., of 6.97.

It has often been noticed that the presence of silicon in pig iron favors the separation of carbon in the form of graphite. In the case of the pig iron in question the separation is perfect. In the analysis given by Mr. Bell there is considerable carbon in the combined form. It is desirable that more analyses of glazy irons from different sources should be made to determine if there is any uniformity on this point. All the analyses show that the total carbon is small in amount when the silicon is high.

AN ACCOUNT OF AN EXPLOSION OF FIRE-DAMP AT THE MIDLOTHIAN COLLIERY, CHESTERFIELD COUNTY, VIRGINIA.

BY OSWALD J. HEINRICH, SUPERINTENDING ENGINEER.

THE responsibility resting upon the owners and managers of mines where fire-damp is generated, renders it a matter of imperative duty that a full and correct statement of any explosion that occurs should be given to the public. But such a statement must be based on the testimony of impartial eye-witnesses or trained experts. Then a sad experience may result in the adoption of effective preventive measures.

In the absence of any official and professional body of mining experts in the State of Virginia, the writer desires to submit to his professional brethren of the American Institute of Mining Engineers an account of an explosion which recently took place in a colliery under his management, and earnestly desires a thorough and impartial discussion on the facts submitted.

Description and Plan of the Mine.—The "Grove" shaft is situated at the nearest point 825 feet from the last old workings upon the Midlothian property, south of the old Pump shaft works. (See Plate III.) The shaft was sunk by the former company, some thirty years ago, to the depth of 622 feet. An incline over 230 feet long, starting in a northwest direction at a depth of 105 feet above the shaft bottom, had been driven to explore the coal on the dip.

A return of very small dimensions had been driven round the shaft on the south side, entering the upcast chamber. With the information obtained from the former company that a seam of coal about four feet thick, at a depth of 490 feet, had been found, and with the information obtained by the present proprietor, R. T. Burrows, of Albion, N. Y., by means of two boreholes on the dip west of the old shaft, in both of which workable seams of coal at various depths had been ascertained, the clearing out and thorough retimbering of this shaft were commenced in March, 1873.

Borehole No. 1, at a depth of 477½ feet from surface, revealed a seam of coal. This borehole was afterwards carried to a depth of 1140 feet to the granite, without finding any other seam of coal. Borehole No. 3, at a depth of 608 feet, revealed the first coal-seam, 14½ feet thick; at 633 feet, the second, 12 feet thick; at 662 feet the third, 1 foot thick, and at 692 feet the fourth, 4½ to 5 feet thick. The borehole was stopped at a depth of 715½ feet.

The coal in the shaft was found at 485 feet. No. 1 borehole being 211 feet distant from the shaft on the dip, the coal was found to be $7\frac{1}{2}$ feet nearer the surface; and at No. 3 borehole, 594 feet distant on the dip, the coal was found 123 feet lower than at the shaft. All of this indicated considerable irregularities in the shape of saddles or dislocations. Therefore it was at once decided to clean out the shaft to the bottom, and drive a crosscut tunnel to No. 3 borehole from the shaft bottom to develop the different basins, and to get a productive shaft in operation previous to sinking another deep shaft still further on the dip, which would probably not be less than 950 or 1000 feet deep.

The Grove shaft, from the beginning, had been provided with a substantial centre brattice, dividing it in a downcast and upcast chamber, the downcast chamber being again subdivided into two hoist chambers. The shaft is in its narrowest section $10\frac{1}{2}$ feet square, allowing an area of 50.7 square feet for the downcast, and $52\frac{1}{2}$ square feet for the upcast chamber. The old return around the shaft was materially increased in capacity, and had not less than 50 square feet at its narrowest section. The old incline, forming previously the main return from the lower works, has very irregular dimensions, but at its narrowest place is not less than 35 square feet.

The main intake tunnel was started near the shaft at an area of 80 square feet for a double track and turnout, diminishing to 72 square feet at the first level north, called the incline level, having there an area of at least 35 square feet, regulated by doors. At the face of the level it has a return brattice of 18 square feet. From thence the intake tunnel, at its narrowest place, is not less than 56 square feet in area to its west end.

During the progress of winning the pit, successive connections, first at the incline level (called California), second, at the 4-feet seam further west, third at the 12-feet seam, and ultimately at the $14\frac{1}{2}$-feet seam, were made with a return tunnel, partially passing through leaders of disturbed ground, or intersecting the saddle connecting with the old incline as a main return.

After the lowest, or 4-feet seam, and the second, or 12-feet seam (which level is also called the big stall), were in progress further south, top levels, 29 feet perpendicularly from floor of lower level, were carried on, and connected respectively at 88 and 78 feet from centre to centre by upsets (at 35°–40° pitch), 12 x 4 feet (48 square feet), and 12 x 6–7 feet (72–84 square feet) in area, connecting by

overcasts with the main return tunnel, 56 square feet in its narrowest place.

The dimensions of the main bottom level in the 4-feet seam are 55 square feet, leaving a clear area of 35 square feet intake and 12 square feet of return at the brattice in the face. The corresponding top level has an area of 40 square feet. The dimensions of the 12-foot level are 150 square feet, with a clean area of 90 square feet intake and 42 feet return behind the brattice at the face. The corresponding top level has an area of 60–70 square feet, being only driven in the top bench of the coal.

From the incline seam, north of the old incline, another upset for an independent return 50 square feet in area had been driven to the upper levels previous to the explosion, in order to increase the capacity of the returns. The coal in this basin being a very rich gas coal, and known for many years to eject a good deal of gas in the mines, necessitated from the beginning of the work provisions for more thorough ventilation by mechanical contrivances. For this reason a substantial fan-house, built of solid masonry and brickwork, was provided in the main engine-house and connected with the upcast chamber by a tunnel near the surface, also lined with brick. This fan-house received a Guibal fan, 23 feet diameter and 7 feet wide, driven by an independent engine of 14 inches diameter steam-cylinder and 30 inches stroke, all of which were within about three days of completion, and actually completed in that time after the explosion.

Previous to the use of the fan, and up to the time of the explosion, natural ventilation had to be resorted to, which was accomplished by means of a cupola 38 feet high and 40 square feet area, placed temporarily over the return arched tunnel to the fan-house, 32 feet east of the upcast chamber. The greatest number of men employed in this mine had never exceeded thirty to forty per shift. The work was carried on day and night in three relief shifts. The ventilation of the mine, except on very warm and sultry days, had been fully sufficient to work under proper care with open lights throughout the main workings; the safety lamps were only needed for examinations, which were strictly ordered twice in every shift. In case of greater depressions in the atmospheric pressure, or when extra large feeders of gas were encountered, or shots had to be fired in gaseous headings, proper notice was given, and the hands withdrawn from the working places. All of this is fully substantiated by testimony given at the investigation held by W. J. Clopton, Judge of Chesterfield County.

On the 6th of March, after the overcast in the 4-foot seam had just been completed, but before the air was freely circulating, through the neglect of the boss in charge of the Monday morning shift to examine the part of the overcast where it is upon its descent to the lower return, and where gas most likely would lodge, the gas was fired by a boy sent for some tools, causing an explosion, by which four men were burned, of whom one died, while the others revived. It is proper to mention that the day previous had also been very warm and sultry.

The map accompanying this description is a true representation of the mine in all its details previous to the day of the explosion, which occurred May 20th, at 1.22 P.M. It is plotted from actual surveys of the superintendent regularly kept up. (See Plate III.)

Circumstances Preceding and Conditions Prior to the Explosion, and the Cause of the Explosion.—On the 9th of May the main work for raising coal in this mine had been stopped for want of sales; it had also been decided to introduce mules for motive-power in the lower gangways. Two sets of hands were kept at work in the 4-feet and incline bottom levels to heighten the same for this purpose. Additional timbering had also to be done in the upcast chamber of the shaft, and the fan to be completed. Accordingly, all work had ceased in the 12-feet seam. The connections for ventilation being kept up, and the works examined, no one was permitted to enter except by permission of the boss. The incline bottom level ejected a considerable quantity of gas. It was formerly, before the various overcasts had been completed, worked by return air, and was found often to make gas very freely after passing some distance north of the old incline. It was decided now to work this section of the pit hereafter by a "split," and consequently an overcast had been constructed of strong timber-work, passing from the main return tunnel over the incline level into the old incline. Previously, a second independent return for the incline bottom level had been driven north of the incline to the upper level.

Each seam in the pit, and each wing of the same north and south of the main intake tunnel, received, therefore, its fresh air directly and independently, having its collective return for the south wing as well as for the north wing of the pit. All of this work was within less than a day of completion previous to stopping the underground work temporarily, to resume it with all facilities for cheap transportation and thorough ventilation. The pit had been examined between the hours of 10 and 11 A.M. by the superintendent

in the 4-feet and incline bottom levels, and as far as the stables, everything being in the finest state for comfortable work. The weather being very warm and sultry on that day (thermometer at 86°), the head underground boss had been notified of the fact, and had even been out of the pit about 12 M. The previous night more gas than usual had accumulated in the suspended ground of the 12-feet seam. It had been noticed at 10 o'clock P.M. by the boss making his round, to be nearly at the bottom of the first upset in said level, bringing it below the collar of the timber, or about eight or nine feet from the bottom of level.

During the night it had again entirely cleared itself, and the relief boss, at 5.30 o'clock P.M., reported the pit clear throughout, having made his trip all around. All of this has been substantiated by the evidence given at the investigation.

An order was given by the superintendent in the morning to gravel the bottom of the new roads laid with fine rock in the rear works. No doubt the head boss entered these works after dinner with some of the putters and his deputy, and while he went on his rounds to examine the back works south of the main intake in the 12-feet seam, previous to his relief from the shift, he sent his deputy, with two putters, north in the return to haul out the gravel. At all events the dreadful report was brought to the superintendent about 1.40 P.M. that the Grove shaft had exploded. Hastening to the scene of the accident, about three-fourths of a mile off, he found the relief boss for the 2 o'clock shift, who had been sitting close to the shaft when the explosion occurred. Two men had come out after the explosion through the main hoist-chamber upon the cage, operated by the steam-engine; one man, working in the upcast chamber of the shaft, had been hoisted up about 350 or 400 feet by the horse-whim used for the chamber temporarily. They reported more men alive at the bottom, and soon the signal from below was heard by the rapid striking of the hammer. Two facts were at once ascertained:

1. The downward cage had hung in the shaft, while the upward-bound cage had come to the top, and probably doubled up the slack rope.

2. Both chambers of the shaft were casting up black damp very rapidly, all of which indicated a break in the shaft.

Mr. George Jones, the relief boss, had already made one attempt to go to the bottom before the superintendent had arrived. On account of some obstacle in the shaft, and in consequence of the foul air prevailing, he could not accomplish his object. The great need

was to restore the current of air to relieve the men yet alive at the bottom of the shaft, and then to ascertain the extent of the damage and to repair it.

For this purpose a waterfall was put in operation with the means at hand. A temporary change could soon be noticed in the shaft. The attempt was now made, by means of a temporary rigging from the horse-whim, to descend the shaft to ascertain the extent of the damage, and if possible to bring relief to the men at the bottom. The former was accomplished by Mr. Jones and James Hall, it being ascertained that just at the entry of the main top return to the upcast chamber of the shaft about 20 feet of centre brattice had been broken out after the last cage had passed, destroying the entire course of ventilation. This centre brattice consisted of main needles across the shaft 8 × 10 inches, placed 6 feet 8 inches from the centre, with corner and centre posts 6 × 8 inches, and lined with 2-inch planks, tongued and grooved, the sides being closed by brickwork and cement against the sides of the shaft. To accomplish the latter, *i. e.*, to go down to the bottom to the men, could not be ventured yet, the two men making the first attempt being nearly overcome by black-damp, one being rendered almost helpless. Orders were now given to get long blankets in order to make a temporary brattice. The timber being knocked out, it was impossible to restore the brattice with planks. During this time the wire rope connected with the cage hung in the shaft had been pulled down. A more rapid communication was again restored; and the waterfall, being kept in constant motion at such places where men were not working in the chamber, furnished air enough to enable the men to remove the broken timber in the shaft and go to the bottom, where the groans of living men could still be heard by nightfall. Two colored men were thus rescued alive, but senseless from black-damp; also the body of the miner precipitated down the shaft was carried up to the surface. The temporary brattice of blankets being now made closer by stitching them together, the interior works could be entered without extra risk, but under great fatigue, by relief squads of men.

The body of the head boss was found at the end of the main intake (at C) in a very mangled condition. His broken watch pointed at 1h. 22m. P.M. as the time of the explosion. A putter (or trailer) was found in the return (at G H), the deputy and another putter (at H & M) also in the return behind the ventilating doors. The pit was searched after the explosion, with the temporary brattice restored, within the forehead of the 4-feet and incline bottom level, and within

the second upset of 12-feet bottom level, although portions of the regulators for ventilation were destroyed.

Three men were still missing. Some of them having been seen at the shaft bottom by those who had come out after the explosion, it was supposed that they might have ventured to escape up the old incline. This was opposed as a matter almost impossible, and no more volunteers were to be found to aid in making such a venturesome trip. But it was now ascertained, about 4 o'clock A.M., from one of the rescued men who had returned to consciousness, that they were last seen by him crawling in the shaft sump to get fresh air. Search was therefore made in the sink of the shaft, and soon the three dead bodies were discovered and brought up to the surface. They had no doubt been killed by the rising of the black-damp, hastened by throwing down the water. It is also most likely that in taking this most unfortunate position in the pit, their deaths might have been hastened by the chilling effect of the waterfall. About 6 o'clock A.M., after sixteen hours of hard and dangerous work to save their fellow-workmen, or at least to recover their bodies, the object was accomplished, and all except those left to attend the two feeble rescued men left for their homes.

In contradiction to public statements made, it may be remarked here that with the exception of one miner, John Kindler, from the Black Heath Mines, who rendered very efficient services, being one of the first that entered the shaft after the explosion, all the aid rendered *in the pit* was by men working at the Midlothian Mines. One other miner from Black Heath, William Marshall, who had lost a son by the accident, although in feeble health from a prolonged sickness, made the attempt to go down and search for his son, but failed to reach the shaft bottom, being overtaken by black-damp. But it must also be stated that at the surface the employés of the company worked untiringly the night through, freely assisted by people of the neighborhood, in relieving the poor sufferers, or in taking care of the unfortunate victims of the accident.

The examination of the mine after the explosion revealed the following facts: Nearly all the damage was done in the 12-feet seam levels, most of it at the first and second upset; nearly all the timbers between those points were kept in position, also those near the face of the level. The doors in the lower return were blown out, also the top part of a wall at the stables, and the overcast to the old incline. Otherwise, except the destruction of the brattice in the shaft before mentioned, no damage of any consequence had been done. The four

men were killed outright in the rear works at the places designated; three men escaped from the breast of the 4-feet seam bottom level unhurt to the shaft, two coming to the surface, one being secured afterwards with the lander at the shaft. They hardly had felt the explosion; even their lamps were not blown out. Three men escaped from the rear of the incline level (their caps and lamps being found at G C), coming unhurt to the shaft, and were only afterwards suffocated by crawling in the sink. The two men working in the upcast chamber were lifted off from the scaffold: one fell in the shaft, the other caught the rope and was brought up unhurt.

Of the four men killed in the rear works, the foreman, found at C, was badly mangled and burnt in the face. The one found at G H was not burned at all, but showed indications of being choked by after-damp. The two found at H and M, behind the doors, were very badly burnt.

From the above we may assume the following as the prime cause of the explosion:

It was known that the first upset in the 12-feet level had been full of gas the night previous, probably extending to some extent north in the overcast, but had cleared itself again during the night, and was found free of gas in the morning. The day being a very sultry one, it had no doubt filled itself again up to dinner-time. The boss, making his examination, went, it is supposed, as usual, with the open lamp as far as that upset. Here, either the gas had come lower down in the bottom level than at any previous time, and through bad judgment he ventured up too high with his open light (both the common and the Davy lamp having been found with his body), or by some accident, as by climbing up a platform, he might have slipped, and fired the gas in his fall. The body was most probably thrown through the level to the place where he was found. The line of fire passed through the upset, and splitting in the top level, following the gas, came down the second upset, making the destruction in rear of the level. In passing north it burned the men behind the doors; but finding there the impediment, the other was suffocated by after-damp. The men in the incline level were saved because the destructive power had to be exerted upon the overcast first, and had, therefore, more time to pass up the incline in a straight direction than by passing north into the bottom level.

This point should be particularly noticed, because during the course of the investigation, as no other subject of blame against the proprietor or the manager could be raised, it was positively asserted by in-

terested parties that this overcast and the opening of the doors from the main intake into the incline bottom level were the prime causes of the accumulation of gas in the mine, and the rear level particularly, and therefore whoever had given the order to open those doors was responsible for the slaughter of the men.

As this subject involves the somewhat perplexing question of "splitting the air," and the effects upon the ventilation, it will be necessary to restate the following facts:

The whole area of the downcast shaft is	50.7 sq ft.
The area of intake, as far as the incline level,	72 "
" doors to incline level, 25 6 sq ft.; its return	18 "
" intake to west end,	56 "
" 4-feet bottom level, 35 sq. ft.; its return	12 "

At the time of the explosion this level in the rear was only supplied with fresh air by an air-pipe 2 square feet in area, and found fully sufficient for all purposes:

Area of 12-feet bottom level, 90 sq. ft.; its return	44 sq. ft.
" return in upset of same level,	25 "
" overcast at incline, at its narrowest point,	35 "
" upcast chamber in shaft,	52.5 "

Suppose now the pit was worked with return air. We would have the following sum of areas:

At 4-feet seam return,	12 sq ft.
At incline stopping, ½ of 35	17½ "
At incline level	18 "
Total,	47½ "
Against an area of the intake equal to	50.7 "

On the contrary, if the pit is worked by the split, we will have the sum of the following areas:

Narrowest return (at brattice) in incline bottom level,	18 sq. ft.
" " in 4-feet seam,	12 "
" " in overcast at old incline,	35 "
Total of returns,	65
Against an area of intake of	50.7

In the former the sum of areas of return is less, in the latter greater than the intake, as it is required by laws of nature, and even by some State laws.

If we take into consideration the distance the air has to travel, the following figures must be considered:

Distances from Shaft Bottom to Bottom of Upcast Chamber.

By 12-feet seam level direct up the old incline, ...	2066 feet.
" " " " through incline bottom level if return air is used, ...	2234 "
Difference in favor of direct air-course, ...	168 "
By 4-feet seam level direct up the old incline, ...	2116 "
" " " " through incline bottom level if return air is used, ...	2284 "
Difference in favor of direct air-course, ...	168 "
Distance from shaft bottom direct through incline bottom level to upcast, ...	1007 "
Distance to pass the air through 12-feet seam, ...	2234 "
Difference in favor of direct air-course, ...	1227 "

The distance for return air in all instances is therefore greater, and for the incline bottom level over double the distance, and this in contracted returns besides.

Without entering further into the mathematical calculations of this subject, these figures will speak for themselves. The amount of friction will increase in proportion to the distance the air has to travel; the air is, moreover, fouled already by the return from two main workings.

To avoid the natural consequences of such a loss of motive power due to friction, thus fouling the air unnecessarily, and, furthermore, to increase the very limited return afforded by the old incline, the system of splitting the air at the first north level, giving it an independent return, was adopted and practiced the day on which the explosion occurred, the rear works not being manned by workingmen. Instead of entering into the lengthy calculations of the various effects of this or that system, with which all present are well acquainted, a few facts may be mentioned to make the true policy more plain to the public.

One of the witnesses in the investigation (Andrew Jewitt) stated that while working in the incline bottom level a day or so previous to the explosion with the doors closed (working by return air), so much gas accumulated in this level that he could not work in it with an open light, and reported it. When the doors were opened he could work with all safety and comfort with an open light.

Another (Thad. Crump, deputy) stated that the night previous to

the explosion, although the upset in the 12-feet level had been full of gas, it had cleared itself again, with the doors left open.

A third witness (G. Jones, boss, and an old miner in gaseous pits) stated that in his opinion more air would enter the back levels with the doors closed, but that from his experience the pit was as safe with the doors closed as opened. Others contested furiously for the closed doors.

To show the effect of temperature when working with return air, even by the use of a fan, the following statement of thermometrical observation, made on the 9th of June after the explosion, may be of interest. The fan was run at thirty-five revolutions, and passed about 23,000 cubic feet of air through the pit.

Temperature at 10 A.M at the surface, ...	79° Fahr.
" " at the shaft bottom, ...	80° "
" " at 4-feet seam bottom level at face, two men at work using powder, ...	80° "
Temperature at 10 A.M. at 12-feet seam bottom level in front of the men, 9 men at work with double sets of lights (Davy lamp), .	70° "
Temperature at 10 A.M. at the face of the incline bottom level, one man at work in return air (overcast not repaired yet), . . .	82° "

Showing the highest temperature in the face nearest to the shaft, but supplied only by return air. The effect of splitting the air was practically demonstrated at Shaft No. 5 of the Mine Le Couffre, near Châtelineau, ventilated by a fan of Fabry's system. Four independent sections were worked by splits, which, being again connected and worked alternately by return air, made either one, two, three, or four independent returns. The proportional results referred to by Ponson were, per minute:

Number of revolutions required by the fan.	Depression.	Motive power.	Volume of air delivered.
By 4 splits 30.0	10	10	10
" 3 " 35.2	18	17.7	9
" 2 " 30 0	23	19.1	8.8
" 1 " 33.6	31	27.4	7.5

When we consider, further, that in a gaseous pit the return air was taken from the most productive source of gas, and used again at points making gas also freely, the former not being in active operation, while at the latter men were required to work, at a time, moreover, when the motive power for ventilation was naturally lessened, it seems to me that the decision what was best to be done could not be a very difficult matter for a disinterested and impartial judge.

With a sincere wish that for public information the members of the Institute may freely express their opinions as disinterested experts, the preceding statements have been more minutely given than may be considered necessary by such as are not familiar with this important subject.

MR. E. B. COXE said that the advantage of splitting the air, even to a greater extent than was done by Mr. Heinrich, has been well proved by experiment and calculation. He would prefer even a greater number of splits than Mr. Heinrich had made to carrying through the mine in a single continuous current all the air together with the gases formed or given off in the workings.

MR. ROTHWELL remarked that while there can be no question of the advantage of splitting the air, it was possible to carry the division too far. The current may be so weakened that it could not mix the air and the explosive gas, or sweep this out, as the miners term it. The total quantity of air circulated would of course be smaller, but the velocity of the current at a given point might be greater, by reducing the number of splits, and velocity as well as quantity is sometimes wanted. He also pointed out the necessity and advantage of government inspection of mines, especially when the inspector happens to be as capable as his friend Mr. Williams, the inspector of the middle district of Luzerne County, Pa., whom he saw present. In the absence of figures he was not prepared to say the splitting had been carried to excess in this case, and Mr. Heinrich was a good judge as to that; but he merely wished to note the fact that it is possible to carry even a very desirable practice to excess.

MR. J. H. HARDEN asked Mr Heinrich what was the total amount of air entering the mine, and how it was split.

MR. HEINRICH.—I do not know exactly. No instruments were at command to measure the velocity of current, which was only ascertained by the common lamp.

MR. HARDEN.—We cannot discuss this question without a knowledge of the amount of ventilation at the time of the accident.

MR. HEINRICH.—It is fully admitted that the current of air passing at the time was weak, probably not exceeding 50 feet velocity per minute in the main intake. But it was as much as the circumstances

admitted. I am also well aware that the principle of splits may be carried to an excess. But the question here is, if in cases when a mine cannot be fully supplied with air, and such cases may occur in the best-regulated pits, is it not the duty for the time being, until the proper remedy can be applied, to supply those places where men have to perform work with the full amount of fresh air, and let such parts of the mine temporarily idle be the suffering territory, if such parts by order of the manager are only to be entered by the man charged with examining the same to detect danger?

MR. T. M. WILLIAMS remarked that he fully agreed with Mr. Rothwell, and quoted from Atkinson on Ventilation and Gases, that owing to the resistance offered by the shafts, we dare not have more than a limited number of splits in a mine, because although each split adds to the total quantity of air circulating, still in each separate split the quantity ultimately becomes less and less, and if the number be too great, the current of each becomes too feeble and slow to sweep into the holes, corners, and places driven in advance of the actual current. Besides this, powder smoke is a long time in being carried away from the workmen. It is also well known that the benefit to be derived depends upon the length of the said splits, and the relation they hold to the main and undivided split, or in other words, the relation of the depths and areas of the shafts to the lengths and areas of the airways forming the workings of the mine.

The objects to be attained by splitting the main currents of a mine into several separate splits are as follows: To increase the aggregate quantity of air, and in consequence to secure more air for each person depending for his health and safety upon the same. And again, to lessen the dangers from explosions of carburetted gas, by confining its train of evils to the territory of one split or part of the mine, and not to the whole, as when one continuous current is used. It is seldom that splitting of air-currents in mines is attempted, unless by persons who understand the benefit to be derived therefrom. There have been thousands of lives lost for want of a proper and systematic splitting of air-currents to one lost by an excess of splitting.

As regards the explosion, it might have been caused through deficient ventilation—caused by a defective system of ventilating, or from want of capacity in the ventilator. Again, it might have occurred independently of any of these causes, through the oversight of some person or persons in executing the orders of the manager or other officers in charge, or by an error of judgment.

Cases had come under his own notice where sober, efficient, and trustworthy subordinate officers and workmen had been the cause of sad calamities, where their own and other lives had been sacrificed.

NOTE ON THE MANUFACTURE OF FORGED IRON WHEELS, ARBEL'S PROCESS.

BY A. HENRY, ENGINEER OF THE NATIONAL CORPS OF MINES, PROFESSOR OF METALLURGY AT THE MINERS' SCHOOL, ST. ETIENNE, FRANCE.

THE manufacture of wheels of metal for locomotives and cars constitutes an important branch of the iron industry, and one closely related, moreover, to many of the conditions of railway practice, such as speed, safety of passengers, and economy of working. It has been, also, since the introduction of iron roads, a subject of constant study on the part both of engineers of construction and iron manufacturers.

The car-wheels at first used in Europe had spokes of wrought iron and a hub of cast iron. Subsequently endeavors were made to make the wheels entirely of wrought iron, by forging successively the different parts which constituted the hub, spokes, and rim. By this treatment the expansion of the heated portions at the last forgings gave rise to interior ruptures in the already cold and finished parts. The metal was thus strained before use, and the wheels broke frequently in service. It was in consequence of these failures, doubtless, that the engineers of this country were led to employ exclusively wheels of cast iron. The railway companies are nevertheless greatly interested in the reduction of the weight of rolling stock, while preserving abundant strength, and by the employment of wrought-iron wheels one may attain this double end if the defects of manufacture which we have just mentioned are avoided. This may be accomplished by making the wheels in such a manner that the different parts are welded at the same time, whereby the interior strains which so frequently give rise to ruptures in wheels successively forged are avoided. This result has been attained by what is known in France as the Arbel process, of which I will give you a short description if you will kindly give me a few minutes' attention.

The process may be briefly summed up as follows: A pile of puddled bars of the general form of the wheel to be made is prepared,

in which the different parts are properly distributed; the pile is heated to a welding heat in a reverberatory furnace, and then forged under a steam hammer, the face of the hammer and the anvil being provided with the appropriate dies. All the parts of the pile are thus welded at once, and there is nothing more to be done to finish the wheel but to remove the fins resulting from the forging, which is effected by special machine tools.

To make the pile it is necessary first to prepare the different parts, to wit: the rim, the spokes, and the hub. The rim is made from a bar of rolled iron, of the profile indicated by the design of the wheel; this bar is cut by shears to the desired length, bent cold by a machine with three rolls, so that the two extremities come in contact, and welded at an ordinary forge fire; thus prepared, it has the form of a perfect circle. By means of a mortising machine, shallow mortises are then made on the internal surface of the cold bar, which are intended to receive the tenons prepared on the ends of the spokes, as indicated on Fig 1, Plate IV.

The spokes are likewise made of bars of iron rolled to the desired profile. They are cut of the proper length, heated at one end, and swaged so as to form on this end the tenon which is intended to fit in the mortise just described on the rim of the wheel (Fig. 2). In the case of light wheels, or those having few spokes, the other extremity does not receive any preparation; if, on the contrary, the wheel is to be heavy, with a considerable number of spokes, it is upset and flattened in the form of a wedge, so that the spokes can be arranged around the same point (Fig. 4). The ends thus grouped together constitute a portion of the mass from which the hub of the wheel is formed.

For light wheels the hub is made of two similar parts, each one being prepared from a puddled bar by bending hot with the steam hammer around a conical mandril; the ring thus produced is reheated and forged under a steam hammer provided with dies, which cut on the circumference the mortises, in number equal to the spokes, and into which the ends of the spokes are subsequently welded (Fig. 5).

To make the pile for a light wheel, the rim is placed on a horizontal surface, a half hub is placed at the centre, and each spoke is then arranged so that the tenon at one end fits into a mortise of the rim, and the other into a mortise of the hub. The whole is wedged, and the second half placed on top when the pile is ready to be heated (Fig. 6).

For heavy wheels the pile is made in the same way, but, as an

already prepared hub is not employed, it is necessary to wedge the spokes tightly together. There is added at the centre of the pile, if necessary, fragments of puddled iron, so as to give the hub of the wheel the dimensions called for by the designs.

For locomotive wheels, with counterweight and crank, there is added at the proper places between the spokes, blooms and pieces of puddled iron in amount sufficient to form the counterweight and crank. These blooms and fragments are bound to the spokes by wires (Fig. 7).

The reheating furnace does not present any special features. The steam hammer is situated near the door of the reheating furnace, each furnace being thus provided with its hammer. Ordinarily two heats are sufficient to forge the wheel, but locomotive wheels of large diameter require sometimes three heats. These repeated heatings are not in any way necessary to the perfection of the welding, which is always complete after the first heating. It is evident that, in consequence of the expansion of the spokes, already tightly wedged cold to the rim and hub, the surfaces to be welded are pressed together before hammering. The pressure thus produced is such that, if the pile is taken from the furnace at a white heat, and allowed to cool without hammering, the different parts will be found to be thoroughly welded, and cannot be again separated, as experience has shown many times. The repeated heatings have for their only object the accurate moulding of the wheels in the dies and the proper distribution of the materials. The attainment of perfect equilibrium around the centre of the wheel is also accomplished.

The French railway companies, to avoid all oscillating and bumping motion of passenger cars, require that each wheel, when placed on a horizontal knife-edge, shall be in equilibrium in all positions, or at least move with a weight of 250 grams applied to one of the spokes at a distance of 50 centimeters from its centre (Fig. 8).

The process of which I have just given a rapid description has been used in France for twenty years for the manufacture of wheels of all designs and sizes, and, as the number of specimens brought by Mr. Arbel to the International Exhibition shows, these wheels of wrought iron are actually in use on all the French and Algerian railways without exception. Many other European roads have adopted them, and up to the present time not a case of fracture has been authenticated.

A CENTURY OF MINING AND METALLURGY IN THE UNITED STATES.

BY HON. ABRAM S. HEWITT, NEW YORK, PRESIDENT ELECT OF THE INSTITUTE.

GENTLEMEN: If my first words were other than those of thanks for the high honor of being called to preside over the American Institute of Mining Engineers, I should do injustice alike to you and to my own sense of the obligation, under which I have been placed by your voluntary choice. When the position was first suggested to me, I resolutely declined to allow the use of my name, on the ground that, by training and occupation, I was not entitled to this honor, which, it then seemed to me, should be conferred only on a professional engineer. In fact, the history of the Institute, which had honored itself, as well as my distinguished predecessors, David Thomas, Rossiter W. Raymond, and Alexander L. Holley, by elevating them to its highest office, seemed to indicate the line and the limit of safe precedent, in which I did not then see how I could be included.

But my scruples were finally removed by the consideration that, as in the course of human industry, the pioneer, of whom Mr. Thomas was so marked a type, must precede the mining engineer, so fitly personified in Dr. Raymond, and be followed by the mechanical engineer, whose incarnation we behold in Mr. Holley; so all these must be supplemented by the man of affairs and finance, in order that "enterprises of great pith and moment" may be prosecuted to a successful issue. I felt, therefore, that I had no longer any right to resist your preference, or to deprive myself of what I must regard as the crowning honor of an active career.

On an occasion like the present it seems appropriate to review the history in this country, during the last hundred years, of those industries which the Institute of Mining Engineers specially represents. There is much in the story with which other members of this body are more familiarly acquainted than myself; yet I fancy that to all of them, and not less to our distinguished and most heartily welcome guests from abroad, a comprehensive outline of the progress of mining and metallurgy in the United States will prove interesting. I ask your attention, therefore, to a condensed account of that subject, embracing a statement of the beginnings of the industry on our shores, of the notable events attending its increase, and of its present

condition after a hundred years of national life. The extent and rate of our progress will be shown more clearly by figures than by words; and I shall offer a series of tables, carefully compiled from the best available sources, and showing the production of each of the leading metals, year by year. This general survey would be incomplete without some account of the legislation of the Federal government with regard to mining, the principles upon which it has been based, the effects which it has produced; and, finally, I shall attempt to point out some causes and agencies which, under our institutions and habits, may be, in my opinion, relied upon to effect certain great ends of technical efficiency, political economy, and social equity, which our government has not attempted, and could not fairly be expected, to achieve.

Many of the topics I have named are more or less familiar to me in my experience as a man of business, a student of public affairs, and a zealous inquirer into the social and industrial problems of the present generation. But the collection and arrangement of facts in my possession, the search for other facts to complete the record, and the orderly expression of the whole in connected form, would have been a labor at this time utterly beyond my powers, already overtaxed by intense and continuous occupation in another sphere, had I not been able to avail myself of the assistance of Dr. Raymond, whose thorough acquaintance with a large portion of the field I was attempting to cover, and whose ready comprehension of the nature of my plan enabled him to render me a service so essential that I cannot consent to omit an explicit recognition of it.

Mining enterprises were among the motive powers to the exploration, conquest, and colonization of the New World. The desire to find a shorter route to the profitable trade of India, and the desire to conquer new territory, wherever it might be found, in the name of some Catholic or Protestant sovereign of Europe, were accompanied, both in North and South America, by eager hopes of the discovery of gold and silver.

The history of the plunder of the metallic wealth and the development of the mineral resources of Mexico and South America, does not lie within my present purpose. The early enterprises of this kind in the northern part of the continent were less successful, though the progress of two hundred years has made them more beneficial to national prosperity, for reasons which I shall, perhaps, be able to indicate.

Gold was found in moderate quantities in use among the Indian

tribes of the present Southern States. The Spaniards under De Soto, following this clue, and led on by stories, exaggerated or misunderstood, of their Indian guides, made a wide superficial exploration in search of the origin of this treasure. They are supposed to have excavated many of the diggings in North and South Carolina and Georgia, which are now overgrown with forests. But no rich deposits appear to have been discovered, and no permanent operations undertaken.

In the great charter of King James, by which, in 1606, the right to explore and settle the North American continent from the thirty-fourth to the forty-fifth parallel, was granted to the London and Plymouth Companies, it was provided that one-fifth of the gold and silver, and one-fifteenth of the copper, which might be discovered, should belong to the crown. One of the earliest expeditions of Captain John Smith, in Virginia, was the exploration of the Chickahominy River, in the hope that it might constitute a water-way to the Pacific Ocean; and one of the next events in the history of the same colony was a mining excitement, such as would be called in our California tongue a "stampede," caused by the supposed discovery of gold; in which, fortunately, John Smith did not avail himself of his official position to take "stock." It is a curious circumstance that gold really occurs in that region, though the glittering dust, of which a ship-load was sent by the deluded colonists to the jewelers of London, proved to be but mica or iron-pyrites; and it seems probable (albeit this suggestion is not based upon any explicit record known to me) that the presence of gold among the Indians, and the discovery of specimens of the quartz or slates of Virginia, containing visible particles of it, gave rise to the general excitement, under the influence of which, without further tests of value, a large amount of worthless material was collected, to the neglect of necessary and profitable industry. From this point of view the Jamestown mining fever was the prototype of many that have since occurred—all of which may be summed up in the general expression, that the mine "did not pan out according to the samples."

A more promising industry was inaugurated at the same time by the sending of a quantity of iron ore from Jamestown to England in 1608. This ore, smelted in England, yielded seventeen tons of metal, probably the first pig-iron ever made from North American ore. In 1620, a hundred and fifty skilled workmen were sent to the colony to erect iron-works; and it is said that a fund, subscribed for the education of the colonists and Indians, was invested in this

enterprise, as a safe and sure means of increase. But, in 1622, an Indian massacre broke up the enterprise; and both the manufacture of iron and the education of citizens and Indians have been obliged ever since, to rely upon other sources of support.

For an interesting collection of facts relative to the beginnings of the iron industry of the American colonies, I refer you to the forthcoming work on that subject, by our fellow-member, Mr. John B. Pearse, to whose courtesy I am indebted for the opportunity to consult the advance sheets of a portion of the book.

According to the statement of Colonel Spotswood, quoted by Mr. Pearse, it appears that, previous to 1724, neither New England, Pennsylvania, nor Virginia, possessed blast furnaces. Their product of iron was from bloomeries only. According to Prof. Hodge, quoted by Prof. Whitney, however, a furnace was built at Pembroke, Mass., in 1702; and another authority states that, in 1721, New England possessed six furnaces and nineteen forges. In 1719 was passed the famous resolution of the British House of Commons, "that the erection of manufactories in the colonies tended to lessen their dependency on Great Britain." Only the earnest protest of the colonial agents prevented the prohibition at that time of the American iron manufacture. The next thirty years witnessed two instructive contests. The first was that of the colonial with the domestic pig-iron manufacture—a competition in which America was favored by the abundance of her vegetable fuel (the employment of mineral coal in iron-making not having yet found introduction), in comparison with the rapidly waning forests of Great Britain. The British manufacture being protected by heavy duties on colonial pig-iron, the latter began to be more and more worked up into bar-iron, nails, steel, etc., at home; and this brought on a new competition with the British manufacturers of these articles. In 1750, a further legislative attempt to regulate this trade was made by Parliament, which decreed the admission of colonial pig-iron duty free, but prohibited the erection in America of slitting, rolling, or plating mills, or steel furnaces, ordering that all new ones thereafter built should be suppressed as "nuisances."

It will be recollected that arbitrary acts of this kind, for the destruction of our infant manufactures, were among the grievances cited in the Declaration of Independence. The extent of the American iron manufacture, during the ante-revolutionary period, can be inferred only from scanty records of exports. These, beginning in 1717 with three tons, had increased, in 1750, to about 3000 tons;

in 1765, the total is reported at 4342 tons; and, in 1771, at 7525 tons, the maximum annual export. The outbreak of the war of course put an end to exportation and caused a great demand for war material, which occupied and rapidly extended the means of manufacture possessed by the country. The expanded iron industry suffered a severe collapse when, at the close of the war, not only this demand ceased, but the reopened ports admitted large quantities of foreign iron—the successful employment of mineral coal, the steam engine and puddling having by that time laid the foundation of English supremacy in the iron manufacture.

The earliest copper-mining company of which we find any record—according to Prof. Whitney, in his excellent work on the metallic wealth of the United States, the earliest incorporated mining company of any kind—was chartered in 1709, to work the Simsbury mines, at Granby, Conn. These mines were abandoned in the middle of the eighteenth century, afterwards bought by the State of Connecticut, and used as a prison for sixty years. Mining was resumed in them about 1830, and after a few years they were again abandoned. The ores were mostly shipped to England, and seem to have been lean. The deposit belongs to the class of irregular bunches, nodules, seams, or limited beds, in the New Red Sandstone, near its junction with trap. This formation was the scene in New Jersey, also, of early mining activity. The Schuyler mine, near Belleville, on the Passaic, was discovered about 1719, and proved more profitable to its owners before the Revolution than it ever has been since that time, to any of the series of individuals and companies that have expended large sums in its development. In fact, the chief blessing conferred upon mankind by the Schuyler mine arises from the circumstance that the first steam engine ever built wholly in America was constructed in 1793–4, at the small machine shop attached to the smelting works at Belleville, my father being the pattern-maker in the party of mechanics sent out by Boulton & Watt for the purpose of erecting an engine for the Philadelphia Water-works in Centre Square. In 1751 a copper mine was opened near New Brunswick; and the Bridgewater mine, near Somerville, was operated previous to the Revolution, though even then, it is said, with much loss of capital. New Jersey's record in copper-mining is not a cheerful one; but her unsurpassed ranges of iron ores may well console her. Betrayed by the treachery of Triassic and trap, she can flee to the shelter of the crystalline schists. Pennsylvania was not without her

copper-mining in the colonial period, the Gap mine, in Lancaster County, having been opened in 1732.

Already during the colonial period the first red gleams of the future glory of the Lake Superior mines had appeared. The intrepid Jesuit fathers, Marquette and others, who penetrated the wilderness from Acadia to the Gulf, to carry both the Cross of their religion and the Lilies of their Sovereign, had made extensive explorations on the Upper Peninsula, and published glowing accounts of the abundance of copper, to which later travelers added legends of gold and precious stones. Before them, the Indian tribes, whose stone tools now furnish subjects of inquiry to the archeologist, had wrought rudely upon the deposits which nature had left in a condition so exceptionally pure as not to need, for the production of limited amounts of metal, the intervention of metallurgical processes. The first recorded mining operations on the part of white men were those of Alexander Henry, near the Forks of the Ontonagon, in 1771. As is well known, however, the active development of this region dates from the publication of Houghton's *Geological Report*, in 1841, and the extinguishment of the Chippewa title by the treaty of 1843.

Lead mining in this country may also claim an ancient origin—as we reckon antiquity. As early as 1651, Governor John Winthrop received his famous license to work any mines of "lead, copper, or tin, or any minerals as antimony, vitriol, black-lead, alum, salt, salt-springs, or any other the like," and "to enjoy forever said mines, with the lands, woods, timber, and water within two or three miles of said mines." As he received also a special grant of mines or minerals in the neighborhood of Middletown, Conn., it is not unlikely that the old Middletown silver-lead mine, the date of the discovery of which is not precisely known, was opened by him or his successors. The nickel and cobalt mines near Chester, in Connecticut, once held to be very promising deposits, are also believed to have been originally worked by Governor Winthrop; but nickel was not valuable in those days; and the lead and copper in these ores do not seem to have been abundant. Unfortunately, now that nickel and cobalt are so valuable as to repay amply the cost of extracting them when they are present in a small percentage only, these Connecticut ores no longer correspond (if indeed they ever did) to the analysis and accounts formerly given as to their niccoliferous character.

The old Southampton silver-lead mine, in Massachusetts, well

known to mineralogists, was commenced in 1765, by Connecticut adventurers; but its operations were suspended by the Revolutionary war. Lead mines in Columbia and Dutchess Counties, N. Y., were also worked at an early period; and, no doubt, all over the country occupied or controlled during the war by the American forces, there were small and desultory surface operations, furnishing lead for the use of the army.

The Indians inhabiting the Mississippi Valley before the advent of the whites probably did not understand the metallurgy of lead. Galena has been found in the Western mounds, but, it is said, no lead. In 1700 and 1701 Père Le Sueur made his famous voyage up the Mississippi, discovering, as he claimed, many lead mines. Lead mining was begun in Missouri in 1720, while that country belonged to France, and under the patent granted to Law's famous Mississippi Company. Mine la Motte, named after a mineralogist who came over with Renault, the superintendent, was one of the first discoveries. It has been in operation at intervals ever since, and is now successfully managed by Mr. Cogswell, a member of our Institute, who may, I think, truthfully claim that he has charge of the oldest mining enterprise still active in the United States. The ores yield a small percentage of nickel and cobalt, as well as lead.

It was in 1788 that Dubuque obtained from the Indians the grant under which he mined until the year of his death, where the city now stands which bears his name. The land was subsequently ceded to the United States by the Indians, and the representatives of Dubuque were forcibly ejected.

Such, then, was the condition of our mining industry at the commencement of our national existence. We occupied but a strip of territory on the Atlantic; and even in that limited area we had scarcely learned the nature and extent of the mineral resources to be utilized. Anthracite and petroleum, quicksilver and zinc, were unknown as treasures within our reach. The rapid extension of possession, government, population, and industry over plains and mountains to the Pacific, which has been effected in a hundred years, is but the type of a conquest and progress which has advanced with equal rapidity in every department of human labor, and nowhere more notably than in the departments of mining and metallurgy. The tables which Dr. Raymond has prepared, and which will be printed to accompany these remarks, show that this country has produced during the century ending with 1875, of gold, about 66,680,000 troy ounces, worth about $1,332,700,000; of silver,

about 201,300,000 troy ounces, worth about $261,450,000; of quicksilver, 840,000 flasks, or 64,206,000 pounds avoirdupois; of copper, 200,000 tons; of lead, 855,000 tons; of pig-iron, 40,000,000 tons; of anthracite coal, 351,521,423 tons (the ton in all these cases being 2240 pounds avoirdupois); and of petroleum, 76,594,600 barrels. The product of these leading industries for the year 1875 were: gold, $33,400,000; silver, $41,400,000; quicksilver, 53,706 flasks; copper, 15,625 tons; lead, 53,000 tons; pig-iron, 2,108,554 tons; zinc, about 15,000 tons; anthracite, 20,643,509 tons; bituminous coal, about 26,000,000 tons; petroleum, 8,787,506 barrels.

In order that a clear idea may be formed as to the relative position now held by the United States in the world of mining and metallurgy, I have selected the production of coal, which is the main reliance for power of all organized industry, and of iron, which is the chief agent of civilization, as the basis of comparison with other nations, using, so far as coal is concerned, the figures given in the 42d Annual Report of the Philadelphia Board of Trade, for the year 1873.*

	Tons.	Per cent.
Great Britain,	127,016,747	46.4
United States,	50,512,000	18 4
Germany,	45,335,741	16 5
France,	17,400,000	6.4
Belgium,	17,000,000	6 2
Austria and Hungary,	11,000,000	4.0
Russia,	1,200,000	0.5
Spain,	570,000	0.2
Portugal,	18,000	—
Nova Scotia,	1,051,567	0.4
Australia,	1,000,000	0 4
India,	500,000	0.2
Other countries,	1,000,000	0.4
Total.	273,604,055	100.0

The following estimate, in round numbers, of the world's present production of iron is taken from various sources, and may be considered approximately correct. The figures for Great Britain and France are those of 1874, and the product of the United States for the same year has been taken. For other countries the estimates

* I wish to acknowledge for these and other figures relating to coal, my obligations to Mr. R. P. Rothwell, who has freely placed at my disposal the very extensive and elaborate compilations of statistics which are to form the basis of an exhaustive paper by his experienced hand on that subject.

are principally for 1871 or 1872, except Austria and Hungary, for which the official returns for 1873 have been taken.

The quantities are given in tons of 2240 pounds.

		Per cent.
Great Britain,	5,991,000	45.2
United States,	2,401,000	18.1
Germany,	1,600,000	12.1
France,	1,360,000	10.3
Belgium,	570,000	4.3
Austria and Hungary,	365,000	2.7
Russia,	360,000	2.7
Sweden and Norway,	306,000	2.3
Italy,	73,000	0.5
Spain,	73,000	0.5
Switzerland,	7,000	—
Canada,	20,000	0 2
South America,	50,000	0.4
Japan,	9,000	0.1
Asia,	40,000	0.3
Africa,	25,000	0.2
Australia,	10,000	0.1
	13,260,000	100.0

An examination of these tables will serve to show that in the products which measure the manufacturing industry of nations, Great Britain stands first and the United States second on the roll, and that there is a clear and almost identical relation between the product of coal and the product of iron. The United States now produces as much coal and iron as Great Britain yielded in 1850. We are thus gaining steadily and surely upon our great progenitor, and in the nature of things, as the population of this country grows, must, before another century rolls around, pass far beyond her possible limits of production, and become the first on the International list, because we have the greatest geographical extent, and our natural resources are upon so vast a scale that all the coal area of all the rest of the world would only occupy one-fourth of the space in which, within our borders, are stored up the reserves of future power.

In a hundred years, we have thus reached a point at which for coal, iron, gold, silver, copper, lead, and zinc, we are independent of the world, with abundant capacity to supply as well our growing wants, as to export these blessings of civilization to other and less favored lands, as soon as our labor and our legislation are adjusted to the conditions which will enable us to compete in foreign markets.

One hundred years ago we proclaimed our political independence, and we maintained it by force of arms; we are now in a position to proclaim our industrial and commercial independence, and maintain it by the force of peaceful agencies against friendly competition.

A striking view of this prosperous development is presented by the magnificent mineral collection under the charge of Prof. Blake, in the Government building at the neighboring Exposition—a collection which constitutes the first worthy National Museum of Mining and Metallurgy.

Never was a century of free government celebrated under such favorable conditions; never was free government so justified by the material results it has produced. But let us not conceal from ourselves the fact that mere growth in wealth, mere development in industry, mere increase in population are not the best evidences of national greatness; and unless our progress in art, learning, morals, and religion keeps pace with our material growth we have cause rather for humiliation than for glorification.

"Whatsoever things are true, whatsoever things are honest, whatsoever things are just, whatsoever things are pure, whatsoever things are lovely, whatsoever things are of good report" constitute the real glory of a nation, without which the magnificent material structure which in a century we have reared, will disappear "like the baseless fabric of a vision."

In a hundred years, as I have said, we have reached a point at which, for every one of the minerals and metals named, we are independent of the world, having the capacity to supply our own growing domestic demand, and also to export to foreign lands.

It is not my purpose to trace in detail the steps by which this degree of progress has been achieved. The narration of successive events alone, without any discussion of underlying causes and accompanying effects, would consume far more time than I could command. So far as the leading epochs of the history are concerned, I think they may be fairly summed up in the following mere catalogue:

1. First of all, must be named the erection in Philadelphia, in 1794, of the first steam engine in America. We celebrate this year the centennial anniversary of a greater power than the United States of America—a wider revolution than our War of Independence. It was in 1776 that James Watt presented to the world the perfected steam engine, all the improvements of which since his day are not to be compared with those which he devised upon the rude machines of his predecessors. In one hundred years, the steam engine has

transformed the face of the world and affected to its remotest corners the condition of the human race. Few changes have been so profound; not one in history has been so rapid and amazing. With reference to the special subject now under consideration, if I were asked what elements had most to do with the swift progress of our country, I should answer, freedom and the steam engine. But deeper even than any organized declarations or outward forms of freedom lies the influence of the steam engine, which has been from the day of its birth, in spite of laws and dynasties, and all accidents of history, the great emancipator of man.

2. *Gold Mining in the South.*—Already Jefferson, in his *Notes on Virginia,* mentioned the finding of a lump of gold weighing seventeen pennyweights, near the Rappahannock; and, about the beginning of this century, the famous Cabarrus nugget, weighing twenty-eight pounds, was discovered at the Reed Mine, in North Carolina. But the great gold excitement in the South followed the discoveries in Georgia, from 1828 to 1830. The maximum of production (probably never more than $600,000 in any one year) was from 1828 to 1845, since which time it has declined to insignificance, though a few enterprises, both in hydraulic and quartz mining, are now actively prosecuted.

3. *The Opening of the Anthracite Coal Fields and the use of Anthracite in the Blast Furnace.*—The first of these events practically dates from the year 1820, although some anthracite found its way to market much earlier, and the second from the year 1839. The latter was followed by the development of the vast anthracite iron industry, which has contributed so much to the prosperity of Pennsylvania. The connection between anthracite and civilization was long ago pointed out by Sir Charles Lyell, in connection with his visit to this country, when he observed in this State, and in this very city where we now stand, the strange phenomenon of a vast manufacturing population, dwelling in neat houses and able to keep themselves and their houses clean. This smokeless fuel is a great moral and æsthetic benefactor. It has also proved specially useful in metallurgy—one process at least, the American zinc-oxide manufacture, being impracticable without it; and in war no one will deny its superiority who remembers how our cruisers burning anthracite, and hence not traceable at sea by their smoke, were able to spy and pursue the blockade-runners, whose thick clouds of escaping bituminous smoke betrayed them. A table of the production of anthracite is given herewith; and some further observations concerning its

control and management will be appropriate under another head of my remarks.

4. *The Use of Raw Bituminous Coal in the Blast Furnace.*—This was introduced in 1845.

5. *The Development of the Copper Mines of Lake Superior*, beginning in 1845 and increasing slowly but steadily to 1862, when about eight thousand tons of ingot copper were produced; then declining for some years, to recover in 1868 and 1869 its lost ground, and since the latter year, by reason of the great production of the Calumet and Hecla Mine, to attain an unprecedented yield. The tables of copper production for the United States, herewith given, show that our present product is not far from sixteen thousand tons, of which three-fourths must be credited to the Lake Superior mines.

6. *The Discovery of Gold in California*, in 1848, or rather its rediscovery, since it had previously been known to both the natives and the Jesuit missionaries, and also to hunters and trappers. The wonderful direct and indirect results of this event have been too often the theme of orators, historians. and political economists to need a further description from me. Its direct result in the way of mining was the rapid exploration of the Western territories by eager prospectors, and the successive development of placer-mines in nearly all of them. It is difficult to fix the dates of these beginnings; but we may assume with sufficient accuracy that gold mining practically began in Oregon in 1852, in Arizona in 1858, in Colorado in 1859, in Idaho and Montana in 1860. With the completer exploration of the country, and the decline of the placer-mines, stampedes have grown less frequent and extensive than in the earlier days. There is scarcely any corner of the country left, except the Black Hills of Dakota, which has not been ransacked sufficiently to show whether it contains extensive and valuable placer deposits; and those districts which present accumulations of gold in such a way as to offer returns immediately to labor without capital have been already overrun. The principal reliance of our gold-mining industry for the future must be quartz and hydraulic or deep gravel mines. These may be expected to maintain for years to come their present rate of production, if not to increase it. In the table of gold production, herewith given, there is, it is true, a falling off of late years; but this is to be attributed to the placer-mines.

7. *The Commencement, about* 1851, *of Regular Mining Operations at the New Almaden Quicksilver Mine, in California.*—The production of this metal in the United States has been thus far confined to

the State of California; and it will be seen from the table of the production of the New Almaden mine, that it has always furnished a large, though of late a waning, proportion of the grand total for the country.

8. The middle of the nineteenth century was crowded with important events in metallurgy and mining. It was in 1856 that Mr. Bessemer read his paper at the Cheltenham meeting of the British Association for the Advancement of Science, which inaugurated for both continents the age of steel. Within sixty days after that event an experimental Bessemer Converter was in readiness at the furnaces of Cooper & Hewitt, at Phillipsburg, New Jersey. But the experiment was not carried far enough to demonstrate the value of the newly-proposed process, and it was left to the late John A. Griswold and his associates to introduce and perfect this wonderful method in the United States. I speak more briefly on this point than its far-reaching importance deserves; but in the presence of one whose acquaintance with it is so profound, and whose services in relation to it have been so brilliant as those of our honored president, Mr. Holley, and of so many gentlemen as I see before me who are worthily associated with him in its glorious history, I could afford to be silent altogether.

9. *The Commencement of the Hydraulic Mining Industry.*—The position of the auriferous slates and quartz veins, on the west flank of the Sierra, with the precipitous mountains behind them, and the broad plain before, has favored exceptionally the formation of deep auriferous gravels in which California far exceeds any other known region. And the same topographical features furnish the two other prime requisites of hydraulic mining, namely, an abundant supply of water and a sufficient grade of descent to permit the use of flumes and the escape of tailings. These advantages the keen-witted miners of the Pacific coast were quick to make available; and I think we may set down the invention of hydraulic mining, which occurred, I believe, about 1853, as an epoch in the progress of American mining. It has given us an entirely new and original branch of the art, involving many ingenious hydrodynamic and hydrostatic contrivances; and it has certainly made possible the exploitation of thousands upon thousands of acres of auriferous gravel which could not have been profitably handled in any other way. The mountain torrents of the Sierra, caught on their way to the Pacific, have been forced to pause and do the work of man. The same agencies that buried the gold among the clay and pebbles of the river-beds are now made to

strip the covering from it and lay it bare again. The hydraulic mines produce, at present, not less than $10,000,000 or $12,000,000 annually; and many enterprises of this kind which have been prosecuted through years of expensive preparation, and are now just beginning to touch their harvests of profit, will add henceforward to the product. I may mention as an illustration the extensive operations of the North Bloomfield and its two allied companies in California, which have expended in works $3,500,000, and will have six deep tunnels, aggregating over 20,000 feet, and canals supplying 100,000,000 gallons of water daily.

10. We must turn for a moment to the East again, to note the commencement of iron mining at Lake Superior, about the year 1856. The extraordinarily pure and rich ores of the upper peninsula of Michigan now find their way, to the extent of a million of tons per annum, in fleets of vessels across the lakes to Cleveland, and are thence distributed to the furnaces of Ohio and Pennsylvania. The similarly pure Missouri ores have built up in like manner their own market. The growth of the Lake Superior iron business is shown in the accompanying table.

11. The next great event in the history of American mining was the discovery, in 1859, that the Comstock lode was rich in silver. This opened an era of activity and speculation which has scarcely ceased since that time. Single districts have been subjected to fluctuating experiences, passing from the first enthusiasm through all the stages of hope to reaction and despair; but though the fortunes of each have risen and fallen like the changing tide, it has nearly always been high water somewhere. Thus we have had a succession of favorites in the way of silver-mining districts, each one crowding its predecessor out of the public notice. Of these the following list includes the most permanently productive: In Nevada, the Unionville, Reese River, Belmont, White Pine, Eureka, Esmeralda, and Pioche districts; in California, the argentiferous district of Inyo County; in Idaho, the Owyhee district; in Utah, the Cottonwood and Bingham districts; in Colorado, the silver districts of Clear Creek, Boulder, and Summit Counties, to which the latest favorite, the San Juan region, may be added. I have named those localities in which mining industry is still active and flourishing. There is a longer and a sadder list, the funereal effect of which I will not intrude upon this festive occasion. But it ought to be remarked, that the apparent failure and abandonment of many districts heretofore does not argue their lack of prospective value. It is, on the con-

trary, amazing that under the adverse conditions surrounding the industry of mining in regions "remote, unfriended, solitary"—though not "slow"—so many communities should have succeeded in taking permanent root. Too much is expected of this industry when it is required to supply the lack of labor, food, transportation, government, and the organized support which in settled societies all the trades and occupations give to each other. Pioneer work is full of peril and of waste; and in view of the wonderful results achieved by our pioneers in mining, it ill becomes us to sneer at the losses and failures which constitute the inevitable cost of such conquests. When the battle has been gloriously won, and the spoils of victory are ours, we do not greatly mourn over the number of bullets that may have been fired in vain.

But through all the vicissitudes of silver mining in other districts, the Comstock mines have maintained their place, an instance of rapid exploitation, and of aggregated wealth of production unexampled in history. Here, too, there have been intervals of failing hope; but a new *bonanza* has always made its appearance before the resources at hand were entirely exhausted; and we have seen extracted from the ores of this one vein, during the past fifteen years, the round sum of $200,000,000 in gold and silver. Dr. Raymond, in the table herewith given, assumes the product of gold to have been (on the authority of Mr. Hague) about 40 per cent. of the entire value. We have, therefore, from the Comstock mines during the period named, $80,000,000 gold, and $120,000,000 silver.

The swift development of these mines, and the active commencement, about the same time, of deep quartz mining operations in California led to a remarkable progress in mining machinery, and to the perfection of two distinctively American processes. I refer to the California stamp mill and amalgamation process for gold, and the Washoe pan-process for silver. Neither of these is so novel in principle as the hydraulic process of gold mining already mentioned; but both of them have received the peculiar impress of an ingenuity and mechanical skill, partly innate in our national character, and partly the product of the stern pressure of economic necessities. Into the fruitful field of further metallurgical improvements born of our Western mining industry—or adopted by it—such as the Blake rock-breaker, the Stetefeldt roasting furnace, the Brückner cylinder, the Plattner chlorination, and many others less widely known, I cannot enter here. Our people have advanced in this line with headlong energy, and accomplished great results—at great expense.

Much, undoubtedly, remains to be done; and it may be hoped that future progress will be equally rapid, but less costly. The introduction, three or four years ago, of the smelting processes of Europe for the treatment of the silver ores of the West, is a striking and encouraging instance of the quickness of our mining communities to seize upon the advantages of experience elsewhere, as soon as they are brought to notice. The ignorance which has led to many disasters in such enterprises, was not voluntary or obstinate. Give our people light, and they do not keep their eyes shut. I am assured that already the smelting works of the West present many features of interest and suggestiveness even to the study of our skilful colleagues from abroad.

12. I may be permitted, in closing this imperfect review, to refer to the great improvements in mining machinery, in rock-drilling, in explosives, in the use of gaseous fuel, in the construction and management of blast furnaces, puddling furnaces, rolling mills, and other branches of the iron manufacture, which have crowded upon us during the last ten years. It is impossible here to give even an enumeration of them which shall do them justice. They have been worthily commemorated in many papers before the Institute. With regard to one of them, the Martin process for the manufacture of open-hearth steel, I may speak with some personal satisfaction, since I had the privilege of introducing it into this country, after studying its merits in 1867 abroad. I am convinced that it has a great future, as the ally, if not the rival, of the Bessemer process.

Returning now to the contemplation of the general field over which we have passed, we may inquire what the Government of the United States has done, with regard to the mining industry. Other nations have elaborate mining codes and bureaus of administration. In comparison with these, the meagerness of our governmental supervision of mining is remarkable; yet, in view of the progress I have sketched, may it not be possible that our system has been on the whole the best for us? Certainly a complicated mining code like that of Spain and Mexico, whatever it may have brought to the coffers of the State, seems to have conferred, in centuries of operation, little benefit upon the people.

The common law of England is the foundation of our jurisprudence in this, as in so many other respects. According to that law, as laid down in a noted case in the reign of Elizabeth, all gold or silver ores belonged to the crown, whether in private or public lands; but any ores containing neither gold nor silver belonged to

the proprietor of the soil. Apart from the claims of the crown, the property in minerals is, according to the common law, *prima facie* in the owner of the fee of the land, but the property in minerals, or the right to search for them, may be vested in other persons by alienation, prescription, or custom. Since the two latter rights require an origin beyond the time of legal memory, they are practically out of the question in this country. The crown right to the precious metals, as declared in the case referred to, was a survival or remainder of the royalty claimed in ancient times by the sovereign over all minerals. This sweeping claim, born of the despotisms of the Orient and made the subject of much conflict among emperors, feudal lords, and municipal authorities during the middle ages, dwindled at last till it covered only gold and silver. But it disappeared entirely from English America, for the simple reason that there was no private land ownership in this country, and the sovereign of England claimed, by right of discovery, soil and metals alike, barring only the Indian title, which it was his exclusive privilege (or that of his authorized representatives or grantees) to extinguish. After the Revolution, the United States succeeded to the rights of the British crown, and by the treaty of peace and the subsequent cessions by the different States of their colonial claims upon the public lands, the federal government became possessed of a vast domain over which, after extinguishing the Indian title, it had complete control. In the territories subsequently acquired from France and Spain, the United States assumed the rights and obligations of those sovereigns; and this circumstance, particularly in the adjustment of Spanish mineral and agricultural grants, has caused some apparent variations from the general policy. But it is sufficiently accurate to say that at the present time, throughout the country, the owner of the fee, or the party who has obtained from him by lease or purchase the mineral right, has supreme control. The mining legislation of the United States, therefore, is simply a part of the administration of the public lands; and for this reason it is executed by the Commissioner of the General Land Office.

In 1807 an act was passed, relating primarily to the lead-bearing lands of Illinois. They were ordered to be reserved from sale, and leased to miners by the war department. The leases covered tracts at first three miles square (afterward reduced to one mile), and bound the lessee to work the mines with due diligence and return to the United States 6 per cent. of all the ores raised. "No leases were issued under this law," says Professor Whitney, "until 1822, and but

a small quantity of lead was raised, previous to 1826, from which time the production began to increase rapidly. For a few years the rents were paid with tolerable regularity; but, after 1834, in consequence of the immense number of illegal entries of mineral land at the Wisconsin Land Office, the smelters and miners refused to make any further payments, and the government was entirely unable to collect them. After much trouble and expense, it was, in 1847 finally concluded that the only way was to sell the mineral land, and do away with all reserves of lead or any other metal, since they had only been a source of embarrassment to the department."

Meanwhile, by a forced construction (afterwards declared invalid) of the same act, hundreds of leases were granted to speculators in the Lake Superior copper region, which was, from 1843 to 1846, the scene of wild and baseless excitement. The bubble burst during the latter year; the issue of permits and leases was suspended as illegal, and the act of 1847, authorizing the sale of the mineral lands, and a geological survey of the district, laid the foundation of a more substantial prosperity.

This policy of selling the mineral lands has been that of the government ever since. But it has necessarily been modified in the West by the peculiar circumstances under which that region has been settled. Before lands can be sold they must be surveyed; and before they can be sold as mineral lands, their mineral-bearing character must be ascertained. Our miners and explorers overran and occupied the Pacific slope in advance of the public surveys. They built cities that were not shown on any map; they cut timber, turned water-courses, dug canals, tunneled mountains, bought and sold their rights to these improvements under laws established by themselves, and enforced by public sentiment only. For nearly twenty years the government looked on, without asserting its dominant ownership of the public lands; and when by the acts of 1866, 1870, and 1872, and other minor enactments, a general system was created, it was necessary to recognize as far as possible the rights which had grown up by general consent, and to seek only to give to them certainty, practical uniformity, and reasonable limitations. It is not my purpose to discuss in detail the mining laws of the United States, or to trace the curiously complicated origins of the local customs on which they are largely based. Suffice it to say that the system recognizes the English common law principle, that the mineral right passes with the fee to the lands; so that, in the words of the commissioner (July 10th, 1873) "all mineral deposits discovered upon land, after

United States patent therefor has issued to a party claiming under the laws regulating the disposal of agricultural lands, pass with the patent, and the Land Office has no further jurisdiction in the premises."

But the principle is also recognized that the mineral right may be separated from the fee by the owner, whether he be an individual or the United States; and this principle is curiously applied in the form of patents for mining claims upon lodes, which, following the form of the possessory title, grant to the patentee the right to follow all veins, the top or apex of which lies within the exterior boundaries of his claim, downward to any depth, though they pass under the surface of the land adjoining.

As the size and the price per acre of the tracts sold under the agricultural laws are different from those to which the mining laws apply, and as, under the homestead law, a certain amount of agricultural land may be obtained without any payment, it is evident, that no known mineral deposits can be acquired under the agricultural laws; and this reservation is enforced both in the preliminary proceedings and in the patents finally issued under those laws.

With regard to the mineral lands, however, it is certain that the patent for a claim carries with it both the fee of the land and also a mineral right, though not the same mineral right as is contemplated by the common law; since it is enlarged on the one hand by the permission to follow mineral deposits beneath the surface of adjoining land, and limited on the other hand by the operation of the same permission in favor of the adjoining owner. The latter limitation is incorporated in agricultural patents also, and may become operative whenever they adjoin mining patents.

Previous to the application for a patent, the law permits free exploration and mining upon the public lands to all citizens and those who have declared their intention to become such. The rights of this class of miners, under what is known as the possessory title, are regulated by local laws and customs, subject only to a few simple conditions, which the United States enforces upon all, and which chiefly concern the maximum size of individual claims, the definite character of their boundaries and landmarks, and a certain quantity of labor which must be bestowed upon them annually, in order to maintain possession. I will not pause to state the different features which these conditions present for lode and placer claims. It is sufficient to say that the miner, conforming to them, and thus maintaining his possessory title, may, after a certain expenditure, and upon due application, survey, and advertisement, in the absence of

any valid opposing claim, perfect his purchase from the Government, receive his patent, and be thereafter free from the necessity of performing any given annual amount of labor to hold his claim. There are features in the present law concerning the rights of prospecting tunnels which seem both obscure and unwise; and some serious questions remain to be settled as to the precise meaning of the law in these and other respects; but these we must pass by.

Looking at the legislation on this subject as a whole, we see that it is confined to one department—that of title. The whole system is devised to facilitate the purchase of the mines by citizens. They are freely permitted to work them experimentally, but it is made their interest to buy them. No inspection, no police regulation, no technical control, is exercised by the Government.

Turning to the State and Territorial Legislatures, we find that they have, in some cases, provided for inspecting mines, in the interest of the safety of workmen. Perhaps the best law of this kind is that of Pennsylvania, in which State the peculiar perils of coal-mining have forced the Legislature to take measures of protection. But we find nowhere such a technical control of mining as is exhibited in many European States, where the Government requires of the miner that he shall not waste wantonly or ignorantly the resources which, once exhausted, will never grow again. Our people waste as much as they like, and no one interferes. Admitting that this is an evil, it still remains a matter of doubt how far, under the circumstances of our particular case, the supervision of authority could remedy it. For my own part, though inclined to restrict as far as possible the functions of government, I am not disposed to say that for so great an end as the conservation of the mineral wealth of the country, it may not properly enforce some measures of economy, with as good right as it may forbid the reckless waste of timber or the slaughter of game out of season. But, in our nation, at least, governmental interference is the last resort, and a poor substitute for other causes, which, in the atmosphere of freedom and intelligence, ought to be effective. We are, perhaps, in our material career as a nation, like the young man who has "sown his wild oats," and now, by mature reflection and the lessons of experience, is likely to be better restrained than by the hand of parental authority.

Permit me, in drawing my remarks to a close, to suggest two agencies which seem to me to be co-operating already, and to open still wider future prospect, for the steady social and economical improvement of our mining and metallurgical industry.

The first of these is the spread of knowledge on these subjects throughout the country. Under this head we must recognize the great importance of that series of explorations of our great Western domain, which was recommended by Mr. Lincoln, with sublime faith in the salvation of his country, in the midst of the civil war, and which has been, by the liberality of the Government, prosecuted under various departments ever since. I need hardly make special mention, in addition, of the reports of the Commissioner of Mining Statistics, which have appeared annually since 1866, and have reflected upon our own community the light of the gathered technical knowledge of the world, while they have in turn exhibited to the world the resources and the progress of America. Such works as these, together with the technical periodicals and the occasional volumes, translated or original, which have come from the American press, have contributed already a great deal to the education of our mining communities. The government has not done too much in this direction; but it seems to me that it should continue this most necessary and proper work in a more systematic and uniform way. There ought to be no conflict of authorities, no duplication of work, no unnecessary expenditure of labor and money in the face of a task so great.

Next in order, I may rank the influence of the technical schools. The number of these has rapidly increased during the past ten years; and I venture to say that many of them compare favorably, in theoretical instruction at least, and several of them in the apparatus of instruction, with the famous schools of the old world. The Massachusetts Institute of Technology, at Boston; the School of Mines of Columbia College, at New York; the Sheffield Scientific School of Yale College, at New Haven; the Stevens Institute of Technology, at Hoboken; the Pardee Scientific Department of Lafayette College, at Easton; the excellent school at Rutgers College, under the direction of Prof. Cook; the new Scientific Department of the College of New Jersey; the School of Mining and Metallurgy of Lehigh University, at Bethlehem; the School of Mining and Practical Geology of Harvard University, at Cambridge; the Scientific Department of the University of Pennsylvania, in this city; the School of Mines of Michigan University, at Ann Arbor; the Missouri School of Mines and Metallurgy, at Rolla; the Polytechnic Department of Washington University at St. Louis; and the similar department of the University of California, at Oakland; and perhaps some others which I have omitted to name—this is a list of schools for in-

struction in the sciences involved in mining and metallurgical practice, of which we need not be ashamed. What our schools undoubtedly need, is a more intimate relation with practice. But this theme I need not touch. It has been ably and amply discussed at the joint meeting last night of the two bodies most fully aware of all its bearings.

One more agency of the spread of technical knowledge deserves special mention. I refer to the influence of societies like the Institute of Mining Engineers. The five years' activity of this Institute has impressed upon the professions which it represents a spirit of union, an enthusiasm of progress, a mutual recognition of the claims of theory and practice, which cannot be too highly estimated. Perfect our schools as much as we may, the association of the young engineer with experienced engineers, the contact of his mind with mature minds, their recognition of his merit, their correction of his errors, constitute the necessary supplement to the school-training. The average man, at least, should not be left to wrestle with his professional career alone. He will make better progress and take more pleasure in it, if he calls to his aid the element of social sympathy, and the intellectual reinforcement expressed in the proverb, "many heads are better than one."

One further consideration, and I have done. The effect of growing intelligence and knowledge in improving our methods of industry would come short of some great ends if it operated only through the self-interest of the individual. Many reforms are beyond the power of the individual; some are not even to his interest. Thus the miner under a possessory title on a gold-bearing quartz vein in Colorado may know that with a greater investment of capital he could manage to reduce his losses of gold in extraction; but the capital may be wanting; or, he may know that by robbing the mine of its richest ores only, and allowing it to cave, he is probably destroying more valuable resources than he utilizes; but the mine is only temporarily his, and he prefers quick gains to permanent ones. So long as the anthracite lands of Pennsylvania were leased to countless small operators, who paid royalty only on the coal which they sent to market, it was useless to explain to them that they wasted a third of the coal in the ground, and another third in the breaker, or that they ruined thousands of acres of coal-beds, overlying those which they recklessly worked. If there were no natural remedy for this wicked waste of the reserved force upon which the future prosperity and comfort of mankind depend, it would be the highest duty

of Government promptly to take into its own hands the direction and management of the mines of coal which society holds in trust for the future; but already it is easy to detect the operation of a new social law developed within the memory of man, yet the fruit of the preparation of the ages during which society has been slowly built up, and matured into its present form and conditions.

To the philosophic observer, the controlling law which runs through the whole history of man, down to the present century, is the law of dispersion, diffusion, distribution, the centrifugal social force, so to speak, which by its irresistible power has tended not merely to scatter mankind over the face of the habitable globe, but through what are termed civilizing and Christianizing agencies to place communities and individuals upon the common plane of equal rights in the domain of nature and before the law.

From the time of the confusion of tongues at the Tower of Babel, through the long history of the early Oriental Empires, which reduced society to the rule of order and then broke up into fragmentary political organizations, retaining, nevertheless, the principles of cohesion acquired by bitter experience; through the Greek and Roman imperial political structures upon which were ingrafted the civilization and the religion which their downfall made the common heritage of the northern barbarians who came for destruction, but were themselves transformed into the apostles of a more liberal and enlightened social organization, this law of dispersion has never ceased to exercise its power and its supremacy. The very inventions of man are only so many proofs of the unceasing operation of this law. In warfare, gunpowder and firearms merely enlarged the area over which it was possible to carry on military operations; the magnetic compass only widened the field of commerce; the printing-press and the telegraph are merely agencies for the diffusion of thought; the steam engine is but a means whereby it becomes possible to establish local industries in every part of the habitable globe; and the canal and the railway are essentially distributers of the products and the wealth of the human race.

Although there is an impression abroad that this age is one of growing concentration of property, no man can study the history and the facts of the development of society without coming to the conclusion that at no period has there been so general and equal a distribution of rights and property as in the present age. The destruction of the feudal system was, in reality, the establishment of a new and better theory, in regard to the ownership of land, which

has borne its legitimate fruits in the subdivision of estates in France, through the convulsions of a revolution; in the more general distribution of landed property in Germany, and in that steady, remarkable, and successful agitation in England, which is now showing its results in the limitation of entail, the simplification of transfer, the enlargement of the suffrage, and the acquisition of small freeholds, whereby political power is being slowly but surely transferred from the great landholders to the middle classes of the most powerful and compact political organization which the world has ever seen.

While, then, there is thus an unmistakable progress in the world towards a juster and more general distribution of the control of the resources of nature and of the fruits of human industry, the present century has, undoubtedly, developed a new and remarkable centralizing tendency, which might be denominated the centripetal industrial force. I speak of the application of the corporate principle to the management of industrial enterprises, producing a concentration of property and management through the diffusion of ownership. Under the corporate system, the number of owners may be unlimited, but the management is necessarily confined to a few hands. It is the political idea of representation applied to industrial enterprises; it is the common wealth in its industrial, and not its political sense, which is concentrated for the material wants and progress of the human race. Now, this law of universal ownership, under limited management, heretofore applied with marked success during the latter half of the present century to great manufacturing establishments in this country, and of late in Europe, and of necessity to railroads everywhere, has at length, by slow but irresistible steps, taken possession of the great mining enterprises of the United States, and to-day has its strongest and most interesting development in the anthracite coal region, which may be said to be monopolized by six great corporations, administered by a very small number of able officers representing a vast body of owners who rely upon steady but not excessive dividends for their support. It is the fashion to denounce these corporations as monopolizers, but it is only the thoughtless who do not investigate below the surface, who take this view of what is really the most interesting and suggestive application in our day of a powerful and irresistible force originating in the very heart of the social fabric. The monopoly is not the monopoly of ownership, for everybody is free to buy and sell, and there is no day when a man with money may not, at its value, procure a share in these enterprises. And no one familiar with business will pretend that

the profits have been out of proportion to the cost and the risk of the undertakings, and no more conclusive answer, to any complaint on the score of monopoly can be made, than that to-day the shares in these corporations, in many cases, are selling below the original money cost. These corporations are, in fact, not the creators, but the outgrowth of a new and beneficent principle, which has begun to assert itself in society, and will continue to grow in power until the end of time. This principle is the practical association of diffused capital, through the agency of corporate organization, with labor, for the promotion of economy, for the improvement of processes, and for the general welfare of mankind.

The capital is derived from innumerable sources, just as the little rills, finally, through streams and rivers, constitute the great ocean. The laborer himself may thus be the capitalist, and the capitalist may thus be the laborer, each taking his share of that portion of the fund which is appropriated to labor and to capital, and often in a double capacity taking a share from both.

In its perfect and ultimate development it embodies the Christian idea of "having all things in common," yet "rendering unto Cæsar the things that are Cæsar's."

The rate of profit which may be derived from these great enterprises, subject as they are to the scrutiny, criticism, and judgment of the public, in an age when nothing escapes notice, and all rights and property are virtually subordinated to the popular will, can never be excessive, for two reasons: on the one side the public will inevitably demand lower prices for an article of primary consequence in every household, and these corporations, creatures of the public will as they are, could not successfully resist such a demand, based upon excessive or unreasonable profits. On the other hand, whenever the dividends rise above a reasonable rate of compensation, the laborers engaged in the production of coal, from whom these profits cannot be concealed, will justly claim, and rightfully secure, a larger share of the fruits of their labor. The checks upon any unreasonable exercise of the power conferred by the ownership under limited management of the anthracite coal-fields, are in reality so powerful that the public have nothing to fear from this cause, but the corporations have rather reason to dread that they may not have justice at the hands of the public and the working classes. This justice they can only hope to secure by the wisest, best, and most economical management and administration of the property they control, and whatever profits they may hereafter derive and be allowed to

divide among the owners, will be rather due to the economies which they may be able to introduce, whereby the article is furnished at the lowest possible rate, than to any fancied monopoly which they may have in the coal itself, or in its transportation to market.

Already, by the application of adequate capital, guided by the largest experience and the highest technical skill, the anthracite coal-mines, from being worked in a wasteful and extravagant manner, are being rapidly put in the best possible shape for the economical delivery of coal at the surface, and for the preservation of every portion of the store upon which the future value of the property must depend. But besides economy in mining and care in preserving, there must be regularity and stability in the operations of the mine. There can be no real profit where these operations are subject to constant interruption, caused by strikes or other artificial impediments. The loss of interest on the plant at the mines, and in the lines of transportation caused by any serious stoppage to the works, would, of itself, be sufficient to render investments of this kind unprofitable. Hence the out-put must be regulated and proportioned to the wants of the market. But this regulation must be continuous and not spasmodic. To enable this to be done, large stocks of coal must necessarily be kept on hand, in order that any sudden demand may be properly met without any serious increase in price; and in dull times the accumulation and restoration of the stocks will give steady employment to the miners, to whose families any cessation of work is a calamity of the most serious character, and to society an unmitigated evil. To insure continuous operations, the best relations must exist between the corporate owners and the laborers in their employ. It is notorious that throughout the coal regions these relations have been of the most unsatisfactory character, resulting, at often-recurring intervals, in strikes and lock-outs, which have no redeeming feature, but, on the contrary, have raised the price of coal to the consumer, have impaired the dividends of the owners, and have reduced the working men and their families to a condition of suffering and demoralization, appalling to every well-wisher of his race. It is fortunate, therefore, that the interests of all classes concur in the prevention of these destructive and demoralizing collisions, and that the owners of the property, for their own self-protection, will be driven to remove the causes which have produced them. It is idle for them to expend their capital for the best machinery, for the highest skill, for the most economical transportation, unless they

can, at the same time, insure a continuous production from a contented laboring population.

This they have it in their power to do. If the same spirit of sacrifice which has sent out our missionaries into every heathen land, had been shown in the coal regions, and the same efforts had been made to establish and maintain the school-house, the church, and above all the Sunday-school, which have borne such fruits elsewhere in this broad land; if the hospital for the sick, and the comfortable refuge for the unfortunate had been carefully provided; if reading-rooms and night-schools, and rational places of amusement had, from the outset, been maintained for a growing and restless population, the coal regions to-day might have been a paradise upon earth instead of a disgrace to civilization. And here it is that this new power of concentrated management can exert itself with sure and absolute success. The appropriation of a few cents per ton on the coal mined to the work of improving the moral and intellectual conditions of the miners and their families will, in a time incredibly short, change the whole face of society in the coal regions.

To be effective, however, this consecration of a fixed amount on each ton of coal sent to market must be as absolute and final as that portion of the proceeds which is devoted to pumping the mines, or driving the gangways. It must not come from grace, but from a sense of duty involved in the ownership of property, and dictated by a wise regard for its preservation and permanent value. Even if this percentage were added to the price of the coal the addition would not be grudged by the public; but in fact no such addition could possibly occur, as there is no surer way of promoting economy in the cost of production than by improving the social condition, the self-respect, and the intelligence of those who are engaged in the work of production, which thus becomes continuous and systematic. Until the great companies thus recognize the duties, the responsibilities, and the opportunities for good, which are offered by the new social development which has rendered their existence a necessity as well as a possibility, they must not complain that they are regarded with distrust, and as enemies, both by the public which consumes their products, and by the working classes who see in them only grasping employers without a conscience. What individual owners could not do, it is easy for these great companies to put in practice; but the effort must be as earnest and serious as is the business of producing the coal and getting it to market. The very best talent must be secured for the organization and management of the various

agencies necessary for the moral, intellectual, and social improvement of the working classes, who must be themselves associated in the administration of the fund created and expended for their benefit. Five cents per ton would produce an annual revenue of over $1,000,000 applicable to this necessary and noble use, and five years of its intelligent and conscientious administration would convert what in some regions has been aptly termed a "hell upon earth" into a terrestrial paradise which would be the pride and the glory of the new world.

What more fitting celebration of the Centennial year of American Independence could be possibly suggested or devised, or how could the advent of the incoming century be better signalized, than by the foundation on the part of the great anthracite coal companies of a new department in their administration for the moral, mental, social, and physical improvement of the workingmen and their families, and by the appropriation of a fixed charge on coal for this purpose. Let each of them select a well-paid and competent agent to devote himself to this work; let the various agencies be wisely organized and surely perfected, and there will be realized one of the greatest triumphs of that gospel which proclaimed, "Peace on earth, and good-will towards men." The example thus set will soon extend itself to other industries, and to every branch of business which can adapt the corporate principle of the concentration of management through diffusion of ownership, the result of which will be that the strange phenomenon, now felt throughout the civilized world, of a general glut of products in the face of general want of them, will never again be witnessed; because, when the working classes, through the diviner agencies of Christian effort, shall have constant employment, and adequate compensation, the sure results of general enlightenment and a cultivated conscience in the use of property, the power of consumption, now so far in arrear, will surely overtake the power of production, and re-establish the equation which nature intended to subsist between them. Thus may be realized that Christian commonwealth which has been the dream of the patriot, the philanthropist, and the statesman, in all ages, in which every man who is willing to work shall find employment, and in which the products of industry will be so distributed that every man shall feel that he has received his fair share of them; in which there will be neither abject and hopeless poverty on the one hand, nor superfluous riches on the other, because the problem of how to distribute capital through the concentration of management will have been fully solved and be

thoroughly comprehended by all classes in the community; in which the quaint questions put by Sir Thomas More, three hundred and sixty years ago, will at length have been answered, and his suggestive commentary thereon have lost its significance.

"Is not that government both unjust and ungrateful, that is so prodigal of its favors to those that are called gentlemen or goldsmiths, or such others who are idle, or live either by flattery, or by contriving the arts of vain pleasure; and on the other hand takes no care of those of a meaner sort, such as ploughmen, colliers, and smiths, without whom it could not subsist?

"But after the public has reaped all the advantages of their service, and they come to be oppressed with age, sickness, and want, all their labors, and the good they have done is forgotten, and all the recompense given them is, that they are left to die in great misery. The richer sort are often endeavoring to bring the hire of laborers lower, not only by their fraudulent practices, but by the laws which they procure to be made to this effect, so that though it is a thing most unjust in itself to give such small rewards to those who deserve so well of the public, yet they have given those hardships the name and color of justice, by procuring laws to be made for regulating them."

Although I quote from the *Utopia*, let it not be supposed that there is anything Utopian or impracticable in the proposition which I have advanced. It seems to me to be the next great step to be taken for the amelioration of the condition of mankind. The law of diffusion which thus far has governed the progress of the human race toward a higher and better plane of civilization, has at length made an effective lodgment in the domain of capital, whereby it is rendered capable of infinite division without impairing, but in effect improving the economy and force of its administration. The reproach that "corporations have no souls," must, and will, next be removed, so soon as the beneficent possibilities inherent in these agencies shall be generally recognized, and those who are called to the management shall see that because capital is aggregated, the primary law on which all property rests, that it is a trust to be administered for the public good, loses none of its force, but can, in reality, only assert itself in all its vigor when concentrated management is brought to bear upon great aggregations of capital. Man did not become a "living soul" until God breathed into him the breath of life. So corporations are mere machines until they are inspired by the associated conscience of society, to which they can

give ready and effective expression, and I look for this expression first from the great coal companies, because their property and their peculiar organizations make it easy as well as profitable for them to put in practice the fundamental idea, that a fixed portion of the proceeds of industry should be invariably devoted to the social improvement of those who labor directly for its development.

If the seed here dropped should take root, as I pray and believe it will, then indeed will the country and the world have reason to rejoice at the industrial developmeut of the last hundred years, and the celebration of this Centennial be the dawn of a better day for the patient sons of toil, who, let it be confessed, with all frankness and humility, have not yet been endowed with their fair share of the good things of this goodly earth.

Population of the United States.

[From the U. S. Census Returns.]

1790,	3,929,214
1800,	5,308,483
1810,	7,239,881
1820,	9,633,822
1830,	12,866,020
1840,	17,069,453
1850,	23,191,876
1860,	31,443 321
1870,	38,558,371

APPENDIX.

Table of Production of Leading Metals and Minerals in the United States during the First Century of National Independence. Prepared by R. W. RAYMOND.

	Anthracite, in tons of 2240 lbs. avoir.	Pig-iron, in tons of 2240 lbs. avoir	Lead, in tons of 2240 lbs. avoir.	Copper, in tons of 2240 lbs. avoir.	Quicksilver, in flasks of 76½ lbs. avoir.	Gold, in dollars, U S. coin.	Silver, in dollars, U. S coin	Petrol'm, in barrels, of 42 gallons.
1819	18,000*	...	...	...	...	...	...	...
1820	1,965	...	...	...	...	...	...	...
1821	3,273	...	...	...	...	...	...	...
1822	4,940	...	...	...	...	...	...	...
1823	9,023	...	...	...	...	...	...	...
1824	13,641	...	4,432*	...	...	...	...	...
1825	38,499	...	1,281	...	...	...	...	...
1826	54,815	...	1,771	...	...	...	...	...
1827	71,167	2,178,239*	3,927	...	...	...	...	...
1828	91,914	130,000	7,815	...	...	...	...	...
1829	133,203	142,000	7,824	...	...	...	...	...
1830	209,634	165,000	7,163	...	...	...	...	...
1831	230,320	191,000	6,646	...	...	...	...	...
1832	448,171	200,000	8,888	...	...	...	...	...
1833	592,210	218,000	9,767	...	...	...	...	...
1834	456,859	236,000	10,552	...	...	...	...	...
1835	678,517	254,000	11,696	...	...	...	...	...
1836	825,729	272,000	14,216	...	...	...	...	...
1837	1,039,241	290,000	11,994	...	...	...	...	...
1838	873,013	308,000	13,512	...	...	...	...	...
1839	957,436	326,000	15 539	...	...	...	...	...
1840	1,008,220	347,000	15,000	...	...	...	...	...
1841	1,115,045	290,000	18,171	...	...	...	...	...
1842	1,286 618	230,000	21,586	...	...	...	...	...
1843	1,478,926	312,000	21 000	...	...	...	...	...
1844	1,899,805	394,000	22,000	2,680	...	...	...	...
1845	2 352,984	486,000	26,500	100	...	...	...	...
1846	2,707,321	765,000	25,000	150	...	...	...	...
1847	3,327,155	800,000	25,000	300	...	20,000,000*	...	...
1848	3,572,695	800,000	22,500	500	...	10,000,000	...	...
1849	3,724,806	650,000	21,000	700	...	40,000,000	...	...
1850	3,863,365	563,755	19,500	600	25,424*	50,000,000	...	...
1851	5,190,690	413,000	16,500	800	24 000	55,000,000	...	...
1852	5,725,148	540,755	14,000	1,000	20,000	60,000,000	...	...
1853	5,940,905	723,214	15,000	1,850	19,000	65,000,000	...	...
1854	6,846,556	662,216	14 000	2,250	27,000	60,000,000	...	...
1855	7,684,542	700,159	14,000	3,000	33,000	55,000,000	...	...
1856	7,999,767	788,515	14,000	4,000	30,000	55,000,000	...	...
1857	7,694,842	712,640	14,000	4,800	28,000	55,000,000	...	...
1858	7,864,230	629,552	14,000	5,500	31,000	50,000,000	1,000,000*	...
1859	9,010,726	750,560	14 000	6,300	12,000	50,000,000	100,000	3,200
1860	9,807,118	821,223	14,000	7,200	10,000	46,000,000	150,000	650,000
1861	9,147,461	653 164	14,000	7,500	35,000	43,000,000	2,000,000	2,113,600
1862	9,026,211	702,912	14,000	9,000	42,000	39,200,000	4,500,000	3,056,606
1863	10,953,077	846,075	14,000	6,474	40,531	40,000,000	8,500,000	2,611,359
1864	11,631,400	1,013,837	14,000	6,518	47,489	46,100,000	11,000,000	2,116,182
1865	10,783,032	831,768	13,165	6,811	53,000	53,200,000	11,250,000	3,497,712
1866	14,233,919	1,200,199	14,342	6,978	46,550	53,500,000	10,000,000	3,597 527
1867	14,345,644	1,305,015	13,662	7,774	37,000	51,700,000	13 550 000	3,347,306
1868	15,810,466	1,431,250	14,636	9,467	37,000	48,000,000	12 000,000	3,715,741
1869	16,375,678	1,711,276	15,653	11,858	33,713	49,500,000	13,000,000	4,215,000
1870	17,819,700	1,696,429	15,922	12,650	29,546	50,000,000	16,000,000	5,659,000
1871	17,370 463	1,707,685	17,854	12 546	31,881	43,500 000	22,000,000	5,795,000
1872	22,032,265	2,539,783	23,106	11,948	30,306	36,000,000	25,750,000	6,539,103
1873	22,828,178	2,560,962	46,661	15 573	28,600	35,000 000	36,500,000	9,879,455
1874	21,667,386	2,401,261	53,219	17,548	34,254	39,600 000	32,800 000	10,910,303
1875	20,643,509	2,108,554	53,000	15,625	53,706	33,400,000	41,400,000	8,787,506
Total,	341,521,423	40,000,000	855,000	200,000	840,000	1,332,700,000	261,450,000	76,594,600

* Including the whole previous period from 1776.

Production of Quicksilver at New Almaden for Twenty-three Years and Three Months.

Dates.	Class and Quantity of Ore			Total pounds.	Flasks from furnaces.	Flasks from washings.	Flasks, total	Average am't per month, flasks.	Percentage, including all.	Percentage, Tierras.	True per ct. of ore ex'ld. tier & w'ngs.	No of months.
	Grueso, Pounds.	Granza, Pounds.	Tierras Pounds.									
July 1850 to June 1851.	.....	.....	.....	4,970,717	23,875	....	23,875	1,989½	36 74	....	36 74	12
" 1851 " " 1852.	.....	.....	.....	4 643 290	19,921	....	19.921	1,660	32 82	....	32.82	12
" 1852 " " 1853.	.....	.....	.....	4,839,520	18,035	....	18,035	1,503	28 50	....	28 50	12
" 1853 " " 1854	.....	.....	.....	7,448,000	26,325	....	26,325	2,193¾	27.03	....	27 03	12
" 1854 " " 1855.	.....	.....	.....	9,109,300	31,860	....	31,860	2,655	26.75	....	26.75	12
" 1855 " " 1856.	.....	.....	.....	10,355,200	28,083	....	28,083	2,340¼	20 74	....	20.74	12
" 1856 " " 1857.	.....	.....	.....	10,299,900	26,002	....	26,002	2,167	19 31	...	19 31	12
" 1857 " " 1858	.....	.....	.....	10,997,170	29,347	....	29,347	2,445½	20 41	....	20 41	12
" 1858 " Oct. 1858.	.....	.....	.....	3,873,085	10,588	....	10,588	2,647	20.91	....	20 91	4
Nov. 1858 " Jan. 1861.	Closed	by Injunc	tion.									
Feb. 1861 " " 1862.	.....	.....	.....	13,323,200	32,402	2,363	34,765	2,897	19 96	....	18 64	12
" 1862 " " 1863.	.....	.....	.....	15,?81,400	39,262	1,129	40,391	3,366	20 22	....	19 65	12
" 1863 " Aug 1863	.....	.....	.....	7,172,660	17,316	2,?48	19,564	2,795	20.86	....	18 46	7
Sep 1863 " Oct. 1863	.....	....	.....	2,346,000	4,820	700	5,520	2,760	18 00	....	15 67	2
Nov. 1863 " Dec. 1863	54,800	1,586,500	718,000	2,359,300	4,040	407	4,447	2,223½	18 65	3	17 52	2
Jan. 1864 " " 1864	1,259,400	18,730,300	3,287,900	23,277,600	42,176	313	42,489	3,540¼	13 96	3	15 64	12
" 1865 " " 1865	2,288,900	25 749,000	3,910,500	31,948,400	47,078	116	47,194	3,933	11.30	3	12.42	12
" 1866 " " 1866.	1,506,000	19,939,100	5 440,200	26,885,300	34,726	424	35,150	2,929	10.00	3	11 62	12
" 1867 " " 1867	731,500	15,689,288	9,603,145	26,023,933	23,990	471	24,461	2,038½	7 19	3	9 42	12
" 1868 " " 1868	2,274,208	14,566,600	12,564,722	29,405,530	25,577	51	25,628	2,1?5⅔	6 66	2	10.12	12
" 1869 " " 1869.	150,000	11 942,175	13,366,000	25,458,175	16,898	....	16,898	1,408	5 07	2	8.48	12
" 1870 " " 1870.	30,000	12,531,900	8,535,800	21,097,700	14,423	....	14,423	1,202	5.23	2	7.42	12
" 1871 " " 1871.	.....	13,661,700	8,373,000	22 034,700	18,563	5	18,568	1,547⅓	6.44	2	9.16	12
" 1872 " " 1872.	142,000	12,777,000	8,497,600	21,416,600	18,391	183	18,574	1,548	6 63	2	9 57	12
" 1873 " " 1873	.....	8,492,375	8,838 000	17,330,375	11,042	....	11,042	920	4 87	2	7 86	12
" 1874 " " 1874	.....	11,294,000	12,160,000	23,454,000	8,867	217	9,084	757	2.96	1.59	4 29	12
" 1875 " " 1875.	.....	12,236,000	18,870,200	31,106,200	13,541	107	13,648	11 37⅓	3.35	1	6 92	12
Totals and averages,	8,436,808	179,195,938	114,165,067	406,457,255	587,148	8,734	595,882	21.35¾	11.21	1.99	14.58	279

Product of Enriqueta from 1860 to 1863, 10,571.

Total product of all the mines on the Company's property, 606,453 flasks of 76½ lbs. each, or 46,393,654½ lbs.—*San Francisco Scientific Press*

Production of Comstock Lode.

1860,	$1,000,000
1861,	2,275,256
1862,	6,247,047
1863,	12,486,238
1864,	15,795,585
1865,	15,184,877
1866,	14,167,071
1867,	13,738,618
1868,	8,499,769
1869,	7,528,607
1870,	8,319,698
1871,	11,053,328
1872,	13,569,724
1873,	21,534,727
1874,	22,400,783
1875,	26,023,036
	$199,824,364

Or, in round numbers, $200,000,000; of which, about $80,000,000 has been gold, and $120,000,000 silver, according to Mr. J. D. Hague.

Production of Iron Ore and Pig-iron at Lake Superior.

Dates.	Ore. Tons	Pig-iron. Tons	Total.	Value.
1856.	7,000	. . . . .	7,000	$28 000
1857.	21,000	. . . . .	21,000	60,000
1858	31,035	1,629	32,684	249,202
1859.	65,679	7,258	72,937	575,529
1860.	116,908	5,660	122,568	736,496
1861.	45,430	7.970	53,400	419,501
1862.	115,721	8.590	124,311	984.977
1863.	185,257	9 813	195,070	1,416,935
1864.	235,123	13,832	248,955	1,867,215
1865.	196,256	12,283	208,539	1.590,430
1866.	296,972	18,437	315,409	2,405,960
1867.	466,076	30,911	496,987	3,475.820
1868.	507.813	38,246	546,059	3,992,413
1869.	633,233	39,008	672,241	4,968,435
1870.	856,471.	49,298	905,769	6,300,170
1871.	813,379	51,225	864,604	6,115,895
1872.	952,055	63,195	1,015,250	9,188,055
1873.	1,066.875	35,245	1,102,120	7,500,000
1874.	840,295	72,740	913,035	6,800,000
1875.	829,115	76,874	905,989	6,900,000
	8,281,698	542,209	8,823,907	$65,575,033

SOME THINGS THAT INFLUENCE THE PRODUCTION OF CARBONIC ACID IN THE BLAST-FURNACE.

BY CHARLES HIMROD, YOUNGSTOWN, OHIO.

In presenting this paper it is not intended to enter into any discussion of the theory of the blast-furnace, but simply to give the results of a number of determinations of CO and CO_2 in furnace gases, and some conclusions arrived at, and the result of an experiment made in hopes of increasing the production of CO_2.

In the first table, on page 198, is given the averages of a number of analyses of gases of different furnaces, and in the second, of two stacks of different sizes under varying circumstances.

The conclusions arrived at as to what influences the production of CO_2 are as follows:

1st. Kind of fuel. Bituminous coal not permitting the formation of as much CO_2 as coke.

2d. Kind of ores. Rolling-mill cinder being much less favorable to formation of CO_2 than hematite ores, magnetites probably less than hematites, but more than cinder.

3d. Length of time of contact of gases with ore. Small furnaces and too rapid driving both waste fuel by not allowing enough time for conversion of CO into CO_2.

4th. The temperature of blast. The hotter the greater the quantity of CO_2.

5th. Regularity of passage of stock through the furnace. The hanging and dropping of the stock, however slight, seems to pack it more solidly in the hearth, increases the resistance to the blast, and decreases the quantity of CO_2.

These are the most common causes noticed which influence the production of CO_2, unless we except the one that might be considered the greatest of all, the one that has spoiled so many tons of iron, and the amiability of so many furnacemen, the one most dreaded, the great unknown.

It would seem a self-evident proposition that the better the contact of the gases with the ore and the less with the fuel, the greater would be the amount of CO_2 produced. To prolong the contact of gas with the ore furnaces are enlarged with advantage, and pains are taken to charge the stock in such a manner as will best promote it. Still, with furnaces of most approved construction and most skilful manipulation, the gases leave the furnace so rich in CO, that not half the heating power of the fuel is obtained, and the highest

blast-furnace authority in the world has given it as his opinion that the limit of economy of fuel under conditions existing in manufac-

Furnace.	Height of stack	Cubic contents of stack.	Cubic feet per ton of iron in 24 hours.	Temperature of blast, Fahrenheit.	Proportion of coke, by weight	Proportion of rolling-mill cinder in charge.	CO_2 to 1000 parts CO, by weight	REMARKS.
1	48	4,200	...	.	all	1/3	200	
			134	500	1/3	1/3	179	
					1/6	1/3	130	
					none.	1/3	110	
2	47	4,500	147	425	1/3	1/2	140	
3	55	4,800	124	427	all.	2/5	138	
4	56	4,800	131	500	1/4	1/4	220	
5	56	6,400	173	500	4-11	2/3	122	
6	75	14,500	. .	..	all.	.	330	Furnace full.
					"	. .	232	Furnace 15 feet down.
					"	. . .	177	" 25 " "
7	60	....	. .	...	...	. .	271	
8	..	...	...	.	.	. . .	128	

HIMROD FURNACE, NO 3, 3200 CUBIC FEET.

DATE.	Engine revolutions	Temp of blast	Coke used	Grade of iron	CO_2 to 1000, by weight.
1875.		° F			
May 6*	20	200	all		46
" 7	20	440	"	. .	158
" 7	20	460	"	.	162
" 8	20	720	"	3	235
" 8	20	710	"	3	314
" 9	20	720	"	3	245
" 10	20	730	"	2 7	241
" 10	24	800	"	3	237
" 11	24	750	"	3	264
" 12	24	770	"	2	282
" 13	24	780	"	1	315
" 14	24	790	"	2 2	306
" 15	28	760	"	2 3	279
" 16	32	830	"	1 5	203
" 19	28	820	"	2	279
" 20	26	750	"	2 5	270
" 23	24	810	"	3	223
" 31	36	880	6-10	1.5	166
June 1	38	900	"	2 2	158
" 22	50	880	1/3	1 3	114
" 30	38	900	"	1 3	155
Aug 11	34	900	"	3	134
" 16	38	840	"	3	165
" 17	38	810	"	3	102
" 18	40	850	"	3	114
" 19	42	850	"	3	135

* Blast put on May 6th.

HIMROD FURNACE, NO 2, 8000 CUBIC FEET.

DATE	Engine revolutions.	Temp of blast.	Coke used	Grade of iron.	CO_2 to 1000 CO, by weight
1875.		° F			
Dec 9*	. .	750	3-5	. .	113
" 10	. .	880	"	.	223
" 10	42	800	"	3	274
" 11	42	750	"	3	285
" 15	50	850	1/3	2	188
" 16	50	880	"	3	351
" 18	52	750	"	1	331
" 19	50	750	1-7	1	403
" 20	48	730	"	2 3	437
" 22	50	760	"	2.7	390
" 23	44	1010	"	2 2	360
" 24	45	880	"	2	420
" 27	44	780	"	2 1	390
" 28	48	950	"	1	374
" 30	46	1000	"	1.1	360
1876.					
Jan 1	42	"	"	1.1	360
" 23	42	"	1/4	1 6	210
Feb. 3	46	"	2-17	3	174
May 1	47	"	1-7	1 7	170
" 2	51	"	"	2.1	218
" 3	52	"	"	2	175
" 4	52	"	"	2 2	296
" 6	52	"	"	3	148
" 7	52	"	"	3	220
" 8	42	1020	"	3	271
" 9	45	"	"	3	206
" 11	50	"	1/3	3	306
" 15	60	1000	1-7	3	250
" 17	52	"	1/3	3	276
June 2	55	"	"	3	331

* Blast put on Dec. 9th.

ture of pig iron in the Cleveland District, England, has been reached when the CO_2 is about 70 parts by weight to 100 CO, and the tem-

perature of the gas is reduced to about 300° C. The same authority has also proved by experiment that CO can be entirely converted into CO_2 by passing it through sufficient quantity of ore at proper temperature, while the reducing power of the gas does not cease entirely until a lower temperature is reached. It would seem possible, then, if the furnace gases were passed through a large body of ore, separated from the fuel, just before its exit, that the quantity of CO_2 might be raised, even above the limit assigned by Mr. Bell, 70 to 100 CO by weight. As an attempt in this direction, a furnace stack, 70 x 15, under repairs the past winter, was constructed with three brick walls crossing each other in the centre, dividing the upper twenty-five feet into six equal compartments, each provided with separate charger and gas-exit. It was proposed to charge, first, some of the compartments with ore and some with fuel, allowing the gas to escape only through the ones charged with ore, or, second, to charge each compartment with ore and fuel alternately, allowing the gas to escape through the ones being charged with ore, but not while being charged with fuel.

By charging in the first method there would be a better contact of the gas with the ore and less with the fuel than in a furnace as ordinarily charged, while passing through the compartments, but just the contrary below. The question would be whether the gain in the one case would more than equal the loss in the other. It was tried and found a failure, the gain about equalizing the loss. Whether it would be possible to construct compartments large enough and whether the gas could be forced through a sufficient body of ore, separated from the fuel, to wholly reduce the ore before it leaves the compartments, are questions this experiment did not furnish any answer to. It proved only that there was no difficulty and no good accomplished in charging this furnace in this manner.

By charging in the second method the final contact of the gas with the ore would be improved, while the contact below would be the same as in a furnace ordinarily charged. The question would be then, is it possible to force the gas through a large enough body of ore separated from the fuel to increase to any extent the production of CO_2 and preserve a good distribution of stock in the lower part of the furnace? With this method of charging it would be necessary to provide the gas-exits with suitable valves. This furnace was not provided with these, as it was not thought advisable to put them in until the first experiment had been tried. To find out whether

any good would probably result, the furnace was charged two days, each compartment alike, and on two different days, three of the gas-exits being closed, ore and flux were charged in the compartments with open gas-exits and the fuel in the others. The following gas analysis shows the result:

Charging all alike with $\frac{1}{3}$ coke, . . .	381 CO_2 to 1000 CO by weight.
With 6 feet of ore and flux in ore compartments,	567 " " " "
" 4 " " " " " $\frac{1}{7}$ coke,	400 " " " "
" 6 " " " " " "	470 " " " "
" 8 " " " " " "	530 " " " "

he experiments could be carried no further, our heavy compact ores making so much smaller bulk than the fuel that the ore compartments could not be kept full. The results indicated so marked an improvement in quantity of CO_2 that valves for the gas-exits were ordered, but before they were made the cross-walls fell in.

This is the history of an experiment and its failure—failure to prove anything very definitely except that we did not build good cross-walls. The Ferrie furnace has shown that compartments can be constructed that will stand, so that the falling in of these walls does not afford any evidence against this plan of construction. The evidence given by this experiment is in favor of a belief that the second method of charging a furnace of this construction will increase the quantity of CO_2 when it is less than 50 parts to 100 CO by weight, with no evidence for or against when the amount produced is over 60 parts to 100 CO.

This plan of construction would be applicable to furnaces of any size using any kind of fuel or ore. The expense of the cross-walls is very little, and the set of small chargers cost less than one large one. By building good cross-walls, placing cast-iron girders on top of them, resting the ends on the lining so that in case the walls give way the chargers would still be supported, the experiment can be made for a few hundred dollars expense and no risk. For, in case the walls falls in, the furnace can be run with the usual way of charging, as this one is now. The brick in the walls will not make very good iron, but smelting them does not seriously interfere with the working of the furnace.

A HISTORY OF THE BESSEMER MANUFACTURE IN AMERICA.

BY ROBERT W. HUNT, GENERAL SUPERINTENDENT ALBANY AND RENSSELAER IRON AND STEEL COMPANY, TROY, N. Y.

THE memorable features of American history have been making fast during the last century, and notably so since 1860; and they are by no means confined to political or to any one branch of scientific development. Of all the industrial arts, none show a greater change or a mightier progress than the Bessemer manufacture. And this year, while we are celebrating the first centennial of our national life, we can also celebrate the first decennial of American Bessemer practice. While not forgetting or undervaluing what has been done in other countries, I have thought that a brief history of the introduction and development of the Pneumatic or Bessemer process in America would be of interest.

In 1863 the Kelly Pneumatic Process Company was formed and an arrangement entered into with William Kelly, who had taken out letters-patent of the United States, Nos. 16,444; 17,628, reissued as 505; 18,910, dated January 10th, 1857; June 23d, 1857; November 3d, 1857; and December 22d, 1857, respectively. This association was composed of the Cambria Iron Company, E. B. Ward, Park Brothers & Co., Lyon, Shorb & Co., Z. S. Durfee, and, later, Chouteau, Harrison & Valle joined the combination. Not satisfied with possessing the control of the Kelly patent, they sent Mr. Z. S. Durfee to England, to secure for this country Mushet's patent on recarburization, No. 17,389, dated May 26th, 1857, the same having been taken out in England on September 22d, 1856. In this Mr. Durfee was successful.

Previous to the application of William Kelly for a patent, Henry Bessemer, of England, had taken out patents dated February 12th, 1856, and August 25th, 1856, in this country. Kelly claimed priority in the discovery of the principles of the process, and the Patent-office allowed his claim by granting him his patents.

In the autumn of 1862 Mr. Alexander L. Holley, while in England, was impressed with the importance of Mr. Bessemer's invention, and so fully foresaw its future, that, upon his return to the United States, he induced Messrs. John A. Griswold and John F. Winslow, of Troy, New York, to join him in endeavoring to possess Bessemer's American patents. Mr. Holley returned to England in

the summer of 1863, but not until the spring of 1864 did he succeed in purchasing for Messrs. Winslow, Griswold & Holley the desired rights.

Thus, at about the same time, there were two separate and distinct organizations seeking to control the future of the then undeveloped industry. While Mr. Durfee was abroad his company determined to erect experimental works at Wyandotte, Michigan (where one of its members, Captain E. B. Ward, owned extensive iron works), with the view of testing the adaptability of American irons to the new process. Mr. William F. Durfee undertook the erection of the plant, and located it in the casting-house of the Eureka Blast-furnace, intending to take the metal direct from the furnace. He put in a 2½-ton vessel with a long narrow casting-pit, and arranged a system of rotary steam-engines to hoist and pour the melted iron into the converter and to rotate the latter. As Mr. Durfee was instructed to avoid as far as possible Bessemer's mechanical patents, he was very much hampered in designing his plans. But it was in these works, in the fall of 1864, under the direction of Mr. William F. Durfee, that the first Pneumatic or Bessemer steel was made in America.

Mr. Z. S. Durfee brought with him, on his return from England, Mr. Lewellen M. Hart, who had acquired some experience in the business at the works of Messrs. Petin, Gaudet & Co., in France. Upon the arrival of Mr. Hart at Wyandotte, he decided to build a reverberatory furnace for the purpose of melting the charges of iron, so as to be able to use a mixture of English and American irons, and it was from metal melted in this furnace that all the steel made by him at Wyandotte was produced. The works remained under this gentleman's charge until the beginning of 1865, when he severed his connection and went to Troy, New York, entering the service of Messrs. Winslow, Griswold & Holley. He subsequently went to the Pennsylvania Steel Works, at Harrisburg, Pa., and afterwards left their employ to engage in other business in Philadelphia, where he died.

In March, 1865, Mr. Ignatius Hahn assumed charge of the Wyandotte works. This gentleman had lately arrived from Prussia, where he had been connected with the works of Krupp, at Essen. He conducted the works until July 4th, 1865, when he resigned his position. As Mr. Hahn's retirement left the company without any practical steelmaker, and the works had thus far been conducted on an experimental basis, the proprietors determined upon making the

most hazardous experiment of all, and put them in charge of the writer, who had gone there a few weeks before, in the interest of the Cambria Iron Company. In accordance with this arrangement the writer made his first "blow," and, by some strange fatality, happened to "turn down" at just the right time.

In the fall of 1865 the reverberatory furnace was torn down, and thereafter, during the continuance of the works, the iron was taken directly from the blast-furnace, excepting that which was sent to the works to be tried experimentally, and which was melted with anthracite coal in a McKensie cupola, this cupola having been put up by the writer during the summer of 1865. In October, 1865, the first heat of Bessemer steel made from Missouri Iron Mountain pig was blown by the writer, it having been melted in this cupola; the resulting steel was extremely satisfactory.

During Mr. Hahn's administration Mr. Z. S. Durfee made several attempts to convert iron melted in the small cupola of a foundry attached to the works, and located on the opposite side of the furnace casting-house. But owing to the cupola being so distant and so small, thus requiring the iron to remain so long in the accumulating ladle, and then to be run so far in an open runner into another ladle, and to be hoisted and poured into the converter, the iron containing also a low percentage of silicon, each trial was a failure. But I believe this was the first attempt to utilize the cupola as a melting furnace for the Bessemer process. At all events, it certainly was the first time it was tried in America, and of its ultimate success Mr. Durfee was fully convinced. Mr. Holley must have been impressed at about the same time with the same idea, for the records of the Troy works show that on July 20th, 1865, the cupola was there used for the first time, and with complete success.

The writer remained in charge of these works until May 14th, 1866, when he turned them over to Mr. A. S. Aubrey and returned to the Cambria works, that company then intending to at once erect Bessemer works. During the year 1865 Captain Ward bought the works from the Kelly Process Company, and they were thereafter conducted entirely in his interest, and, after many alterations, finally abandoned in 1869.

Upon Mr. A. L. Holley's return from England, in the spring of 1864, he at once commenced the erection of a 2½-ton experimental plant at Troy, New York, for the firm of Winslow, Griswold & Holley, and started it February 16th, 1865. While at the Wyandotte works steel was made at an earlier date, the Troy establish-

ment was the first to bring the process near to a commercial success. Not having been personally connected with these works during those early days, I cannot so fully realize the doubts and difficulties through which they passed, but I do know from the Wyandotte, to say nothing of any later experience, that it has required faith made perfect, to carry one through the sea which seemed to be bounded by no shores. As I have often expressed it, if we, knowing there was a way through all our troubles, felt so hopeless, what must have been Bessemer's pluck, to enable him to persevere through his difficulties, when the desired end was known only through faith!

But, before entering into chronological details of subsequent works, I must here state that, after building the first experimental plant at Troy, Mr. Holley seems to have at once broken loose from the restraints of his foreign experience, and to have been impressed with the capabilities of the new process. The result is that mainly through his inventions and modifications of the plant we, in America, are to-day enabled to stand at the head of the world in respect of amount of product.

But to return to the detailed history. As before stated, there were, in 1865, the two rival organizations claiming control of the process in this country,—the Kelly Process Company, through their Kelly and Mushet's patents, and Messrs. Winslow, Griswold & Holley, through their Bessemer and Holley American patents. Both parties felt strong in their respective positions, and in possessing the necessary means to maintain them. But, after spending large sums of money in counsel fees, they wisely concluded that their fight would at best be a "Kilkenny cat" affair, and so, early in 1866, they combined their respective interests, the Bessemer, or Winslow, Griswold & Holley, party taking 70 per cent., and the Kelly Process Company 30 per cent. of all royalties collected. To this wise compromise may we attribute the subsequent establishment of many works. Under this organization Messrs. John F. Winslow and John A. Griswold, of Troy, New York, and Daniel J. Morrell, of Johnstown, Pennsylvania, were elected trustees, and they appointed Mr. Z. S. Durfee their general agent.

But great difficulty was even yet experienced in inducing capitalists and manufacturers to attempt the introduction of the new manufacture. While the metal produced was wonderful in its qualities, still the necessary first outlay was so large, and the details of the process were so uncertain, and the time-honored prejudice against anything new, held such powerful sway, that our people hesitated,

doubted, and waited. Wonderful tales came to us of what was being done abroad, and some venturesome railway managers even dared to import and place in their tracks trial lots of foreign Bessemer rails.

Messrs. Winslow, Griswold & Holley had, from the very first erection of their works, wisely pursued the plan of extending every facility to blast-furnace owners, in all parts of the country, to have their irons tried for steel; and under this system many brands were tried, and most were found wanting. These failures to obtain good results, of course, built up still greater barriers against the spread of the process. In the light of our present chemical knowledge of the manufacture, it is amusing to think of firms sending a few tons of iron to Wyandotte, Troy, or even England, to be tried in actual practice, when a few hours of laboratory work would have settled the entire question. But still it was this very blind using of unknown irons that first opened the eyes of steelmakers to the possibility of making good product from metals pronounced unfit by the then authorities.

The records of the Troy Steel Works show that on March 1st, September 26th, November 22d, and November 30th, 1864, trials of Wassaic, Copake, Fort Edward, Hudson, and Crown Point irons were made, in Henry Bessemer & Co.'s 1½-ton vessel, in Sheffield, with the following results: Wassaic, "slopped over badly, but hammered very well; very hard and not very ductile. Small ingot reheated when hot from mould, and crumbled under the hammer." Copake, "slopped some, hammered tolerably well; harder and less ductile than Wassaic." Fort Edward and Hudson, "worthless, and crumbled under the hammer." Crown Point, first trial, "a little sloppy, very ductile, pretty soft, no cracks;" second trial, "blew well with moderate blast; very good." The earlier of these were, undoubtedly, the first trials made of American irons.

In accordance, I presume, with these results, I find that the first conversion made at Troy was from Crown Point charcoal iron, the first at Wyandotte having been from Lake Superior charcoal, direct from the blast-furnace. The success of the Troy works, whenever good metal was used, encouraged the proprietors to commence the erection of new works on a more extended scale, and early in 1867 Mr. Holley completed the new or 5-ton plant, Mr. John C. Thompson then being superintendent of manufacture. Mr. Holley at this date assumed personal charge of the Pennsylvania Steel Works, having previously furnished plans for the machinery, and Mr.

Thompson soon after took charge of the Cleveland Rolling Mill Co.'s works. Mr. Z. S. Durfee then entered upon the management of the Troy works. He built the forge, and made some alterations both in plant and details of manufacture. Among other things, he adopted for the small or experimental plant the practice of melting the recarburizing metal in crucibles, and obtained most excellent results. At this time the capacity of the works was stated to be forty tons of ingots per day, but the records of the works fail to show any such actual results.

On October 19th, 1868, the roof of the 5-ton plant caught fire and was almost completely consumed, destroying much of the machinery. Soon after Mr. Durfee resigned his connection with the works, and Mr. Holley once more became the manager, the property having been possessed by the firm of Messrs. John A. Griswold & Co., Mr. John F. Winslow selling to them his interest. Upon rebuilding, Mr. Holley availed himself of his Harrisburg experience, and remodelled the works in a great degree, particularly as to the melting or cupola house and the blowing engines. The first blow was made in the rebuilt works, on January 12th, 1870. The small plant had been running most of the time while the large works were being rebuilt.

The ingots produced at these works, up to January, 1871, had either been hammered in the forge or bloomed from 9-inch ingots, at the Rensselaer Rail Mill and the Spuyten Duyvil Rail Mill, and then rolled into rails at these respective establishments. In January, 1871, Mr. Holley had a 30-inch three-high blooming train ready to run, having located it in the forge; he used the hammer already there, to cut and chip the blooms as they came from the rolls. The mill was provided, front and back, with lifting-tables, containing loose rollers, and raised by hydraulic power. The rolls were turned to receive 12-inch ingots, which were cast heavy enough to make two-rail blooms. These ingots, after being placed on the rollers of the front table, were pushed into the rolls, both front and back, by hand, it requiring the power of eight men to operate the mill. The train was built with the top and bottom rolls stationary; the middle roll was moved up and down by four screws running through the bolsters carrying the necks of this roll, these screws being rotated by a friction-clutch, which was driven by a belt off the main shaft of the mill engine, and reversed by a hand-lever at the end of the rolls. This mill proved to be a great advance upon the old practice, and ran until the fall of 1872, when

George Fritz's patent driven table rollers and pusher were added. By the use of these tables the force was reduced to four men, or, rather, three men and a boy.

The works continued steadily running after being rebuilt, Mr. Holley relinquishing the management in 1871, but still retaining a connection as consulting engineer, which position he still holds. He was succeeded by Mr. Barney Mee, who died February 11th, 1872. His place was filled, for a short time, by Mr. John C. Thompson, who returned to the scenes of his first experiences, but, his health failing, the works were without a head until October 1st, 1873, when the writer assumed control. Mr. J. Wool Griswold has been in direct charge since May 1st, 1875. On March 1st, 1875, the firm style was changed to "The Albany and Rensselaer Iron and Steel Company."

I must be permitted to mention, as an amusing incident, and as showing how little we can foretell what time will bring forth, that in 1865, while connected with the Wyandotte works, I called, in passing through Troy, at the steel works, and presented a letter of introduction to Mr. Holley, who, in the gracious manner of which he is so capable, most blandly, but equally firmly, declined letting me inside the works, and, with the best grace possible under the circumstances, I bowed myself out of his presence. Ten years later I am in charge of the works, proud to consider Mr. A. L. Holley my most intimate friend, and very careful to frequently remind him of our first interview. These works are now producing about 1300 tons of ingots per week, which is sufficient to keep the rail mill running double turn. Their largest month gave a yield of 5498 gross tons.

The Pennsylvania Steel Works were the third Bessemer works started in the United States. The company was organized under the presidency of S. M. Felton, Esq., and under the auspices of such prominent railroad men and engineers as the late J. Edgar Thomson, Nathaniel Thayer, M. W. Baldwin & Co., William Sellers & Co., Bement & Dougherty, R. P. Parrott, H. R. Worthton, Merrick & Sons, Morris, Tasker & Co, and others. Upon the first organization of the company Mr. William Butcher, of Sheffield, England, was elected as the engineer, and ground was broken, but, later, other arrangements were made, and the works were built upon plans furnished by Mr. A. L. Holley, and on January 1st, 1867, that gentleman severed his connection with the Troy works and, removing to Harrisburg, assumed entire charge of the construction,

being assisted by Mr. H. S. Nourse. In June, 1867, the Bessemer works were first started, and have been ever since in constant operation. The rail mill of the company not then being completed, most of the ingots were rolled into rails at the Cambria Iron Works, Johnstown, Pennsylvania, this arrangement lasting until May, 1868. I find it stated, in an official publication of July 27th, 1868, that the "annual capacity of the present Bessemer plant (two 5-ton converters) is about 10,000 tons, and of the rail mill 30,000 tons. Additional converters will be erected from time to time." The time for such additions has not yet arrived, but the product has been increased fully five hundred per cent., the heaviest day's product up to date having been 281; week, 1291; and month, 5455 gross tons.

The writer had charge of the rolling, at Cambria, of the Pennsylvania Steel Company's steel, and well remembers with what proud satisfaction Mr. Holley visited Johnstown and proclaimed to us all that at last his dream was realized; that the Pennsylvania works were making four conversions on each turn, or eight per day, producing forty tons of ingots. I presume that "official document" was inspired just about this time. In May, 1868, the rail mill was completed, and since then the company have taken care of their product at their own works. At first they pursued the same plan (rolling 8¼-inch ingots with a reheat) under which their steel had been rolled at Cambria, but subsequently introduced hammering; two hammers have up to the present time drawn the ingots into rail blooms, but the company are now erecting a blooming mill constructed by Mr. James Moore at Bush Hill Iron Works, Philadelphia.

Upon Mr. Holley's relinquishing the management of these works, in 1868, he was succeeded by the joint management of Mr. Nourse and Mr. John B. Pearse. This arrangement was in turn succeeded by another, by which, in 1870, Mr. Pearse took charge of the company's business as general manager, Mr. Nourse remaining as superintendent. Mr. L. S. Bent is now in charge of the works.

The first ingots made at Harrisburg and sent to Johnstown to be put into rails, were drawn into blooms under a 5-ton hammer. A limited number were also hammered at the works of Seyfert, McManus & Co., Reading, and the blooms sent to Cambria. While watching the behavior of the steel under the hammer, Mr. George Fritz, chief engineer of the Cambria works, became convinced that it was not the proper manner of treating the material, and he and Mr. Holley had many consultations on the subject. Mr. Fritz at once turned

up a set of blooming rolls which he placed in a 21-inch rail train, and Mr. Holley caused 8¼ inch ingots to be cast and sent him. These were drawn to 6½ inches square, then recharged and wash-heated, and then rolled into rails. So well did this work, that Mr. Holley adopted the system in the Pennsylvania Steel Company's rail mill, which he was then building. After many discussions and consultations he decided, on his return to Troy, to build the heavier blooming mill to which I have before referred.

The Freedom Iron and Steel Works, near Lewistown, Mifflin County, Pa., were the fourth Bessemer Works started in this country. They were organized under the presidency of Mr. John A. Wright, and absorbed the interests of the Logan Iron Company, which company had been successfully working for many years. Mr. Wright visited England, and made purchases of the most complete machinery there known, and with the exception of the blowing engine, which Messrs. I. P. Morris & Towne, of Philadelphia, built, the works may be said to have been of English construction and arrangement. The company intended to manufacture principally boiler plates and tires, but the plate mill, which was driven by a Ramsbottom reversing engine, was soon changed to a rail mill. The works were under the direction of Mr. R. H. Lee, and ran for about one year, when, owing principally to the unsuitableness of the company's irons for Bessemer steel, the works were stopped, and much of the machinery subsequently sold. Their first blow was made May 1st, 1868.

The Cleveland Rolling Mill Company's Bessemer Works, situated at Newburgh, six miles from Cleveland, were the fifth works erected. These were built after the same general plans as the Pennsylvania Works, but Mr. H. Gmelin, the engineer in charge of construction, made many modifications. This gentleman returned to Austria before the blowing in of the works, which task was assumed by Mr. John C. Thompson, he making the first blow on or about October 15th, 1868. Mr. Thompson soon resigned the charge, owing to failing health, and the works have since then been conducted by Mr. Chisholm. In a short time, a second pair of 5-ton vessels were erected, and all four remained in operation until 1875, when the later pair were removed to make way for Siemens-Martin furnaces, which are now running.

This company deserves credit for being the first parties in this country to make a commercial success of the application of Bessemer steel to wire, screws, and several other specialties.

The Cambria Iron Company, of Johnstown, Pa., were the sixth

parties to build Bessemer Works, their first blow being made by the writer on July 10th, 1871. As stated, the Cambria Iron Company did not erect Bessemer works until after five other concerns had started theirs, but nevertheless they were the very first corporation to give encouragement to attempts to perfect the new process. When Mr. Kelly turned his attention to endeavors to shorten the process of refining iron by blasts of air, he was part proprietor and manager of a blast-furnace at Eddysville, Kentucky. As in the case of many another seeker after the unknown, he spent all of his own money, and seriously embarrassed himself. It was about this time that Bessemer obtained his American patents. After filing his claims as the original discoverer, Mr. Kelly succeeded in interesting the Cambria Iron Company, and under its patronage he transferred his experiments to its works at Johnstown, in 1859, and there met with the usual number of encouraging failures.

The first Bessemer converter ever erected in America, was built at Cambria, by Mr. Kelly, and still remains there, a cherished relic. It was calculated to convert about half a ton of metal, and received its blast from the foundry blowing engine. But I never heard even a tradition of a perfect conversion made in this vessel. Still the Cambria Company, and more particularly its general manager, the Hon. Daniel J. Morrell, were impressed with the possibility of success, and when the Kelly Process Association was organized, the Cambria Company was among the most earnest members. But the conservatism of other members of the company prevailed, and they did not complete their Bessemer works until 1871.

Their chief engineer, George Fritz, had been personally familiar with all of Mr. Kelly's experiments, and had closely watched the progress of the process as developed by Bessemer and others, and during the time the steel made at the Pennsylvania Steel Works was rolled at Cambria, he had abundant opportunities of studying the manufacture in its various mechanical details, and fully realized the advantages of the innovations introduced in the arrangement and details of Bessemer plant, by Mr. Holley. These two gentlemen had been thrown, during this time, into the closest personal intercourse, and while Mr. Fritz was only too happy to assist Mr. Holley with his advice and large experience in perfecting the plans of the rail mill for the Pennsylvania works, he was equally willing to avail himself of the latter's experience and advice in arranging his plans for the Cambria Bessemer plant.

But George Fritz could not blindly copy, and while cheerfully ac-

knowledging everything taken from Mr. Holley, he introduced many new ideas in his arrangement of plant. He built vertical, disconnected blowing engines, and arranged his converting building under one roof, without any dividing wall between the melting and casting houses. And when he came to the blooming mill, he introduced the entirely new features of driven rollers in the tables, and a hydraulic pusher for turning over and moving the ingots on the tables. These two features constitute the Fritz Blooming Mill patent, now used by most of the Bessemer works of this country. The merits of rolling as compared with hammering had been fully discussed between Mr. Fritz and Mr. Holley, and they had, at various times, gone over the numerous details of a blooming mill, and Mr. Holley, as already stated, had built one at the Troy works. Mr. Fritz had availed himself of the benefit of the extensive knowledge and sound judgment of his brother, Mr. John Fritz, of Bethlehem, Pa., and the result of all was the Johnstown Blooming Mill, which marked a new era in the Bessemer manufacture. While living to see many difficulties overcome, and great progress made, George Fritz died too soon, his country losing one of her noblest and ablest sons. He died August 5th, 1873.

The writer remained in charge of the works until September, 1873, when he went to Troy, and was succeeded by Mr. John E. Fry, who is still in charge. The greatest yield at these works has been as follows: March 21st, 1876, 297 gross tons in 24 hours; week ending May 20th, 1876, 1475 gross tons; month ending March, 1876, 6051 gross tons.

The seventh works to go into operation, the Union Iron Company's, are owned by the same parties who control the Cleveland works, and are located at Bridgeport, or South Chicago, Ill. Their first blow was made on July 26th, 1871, and the works have been in almost constant operation ever since. They contain two 5-ton vessels, and the general arrangement is similar to the Newburg plant.

The North Chicago Rolling Mill Company, of Chicago, Ill., built and started the eighth Bessemer works. Captain E. B. Ward, of Detroit, was one of the heaviest owners in this company, and he, as before stated, had owned the Wyandotte works, and was fully convinced of the merits of the process, and while abandoning the last-named establishment, took steps to have a larger and more complete plant erected in Chicago in connection with the extensive iron works of the company. Mr. A. L. Holley was engaged to furnish the plans, and the works were erected under the direction of Mr. O.

W. Potter, then the general superintendent of the company. Mr Holley, profiting by the experience acquired in building the several other works with which he had been connected, and by the already advanced state of the art, introduced many improvements in the arrangement of this plant, and when completed it was undoubtedly the most perfect in existence. The first blow was made on April 10th, 1872, under the direction of Mr. Robert Forsyth, who had received his Bessemer education at the Troy works. This gentleman has ever since remained in charge of the converting works, and has been most eminently successful in his management. His works are to-day making the largest output of any in the world. The plant contains two 5-ton vessels. I might here say that while all the present American plants are said to consist of two 5-ton converters, the general practice is to convert nearer six tons in them. The ingots are bloomed in a three high 30-inch mill with the Fritz tables.

The records of the North Chicago Company show their largest product for 24 hours to have been 330¼ gross tons; for one week 1583 gross tons; and for one month 6457 gross tons.

The Joliet Iron and Steel Company, having rolling mills at Joliet, Ill., and blast-furnaces at Chicago, determined to erect the ninth Bessemer plant in connection with their Joliet works. They purchased of the Freedom Steel Company their blowing engine, converters, hydraulic cranes, etc. Mr. Holley was engaged to furnish the plans, and the works were built under his general direction, Mr. A. L. Rothman and Mr. P. Barnes being the engineers in direct charge. The converting plant consists of two 5-ton vessels, and the blooming train is similar to that of North Chicago. The general arrangement of the two converting works is also very similar. The first blow was made on March 13th, 1873, under the direction of Mr. Dunning, who still remains in charge of the works. Their records show the greatest product in 24 hours to have been 350 gross tons; in one week 1528 gross tons; and in one month 5367 gross tons.

The tenth Bessemer plant was built by Mr. John Fritz for the Bethlehem Iron Company, of Bethlehem, Pa., of which he was, and is, general superintendent and chief engineer, Mr. Holley being connected with him as consulting engineer. Mr. Fritz had studied the various American plants, and also visited England and the Continent, and after mature deliberation concluded to take a new departure. . He arranged his melting-house, engine-room, converting-

room, blooming and rail mills, all in one grand building, under one roof, and without any partition walls. He placed his cupolas on the ground and hoisted the melted iron on a hydraulic lift, and then poured it into the converters. The spiegel is melted in a Siemens furnace, also on the ground floor, and the melted spiegel is also hoisted and poured into the vessels.

The blooming train has the middle roll stationary, the same as the Cambria mill, the top and bottom rolls screwing up and down. Instead of depending upon friction to drive the rollers of the tables, Mr. Fritz put in a pair of small reversing engines. This feature has since been adopted in a method which dispenses with belts, by means of a direct connection of the engines with the table, as arranged by Mr. Holley, in several of the other works. The works made their first blow on October 4th, 1873, under the charge of Mr. Owen Leibert, who is still the superintendent. The highest product has been 264 gross tons in 24 hours; 1340 gross tons in a week, and 5282 gross tons in one month.

The Edgar Thomson Steel Company, limited, of Pittsburgh, Pa., were the eleventh parties to enter the business, locating their works at McKinneys, now called Bessemer Station, on the Pennsylvania Railroad, about nine miles from Pittsburgh; Mr. Holley furnishing the plans and Mr. P. Barnes being the resident engineer, he having severed his connection with the Joliet Works. In the fall of 1873, Mr. William R. Jones, who had been George Fritz's assistant at Cambria, became connected with the Edgar Thomson Company, and upon the starting of the works in August, 1875, assumed charge of them. He is now the general superintendent of the company. The largest product for 24 hours has been 265 gross tons; largest for a month's work, 5403 gross tons.

In arranging these works, Mr. Holley made many improvements over any of his previous efforts, and assisted as he was, the works stand to-day as a fit monument of the progress of the Bessemer process in this country.

The twelfth and last works to start were those of the Lackawanna Iron and Coal Company of Scranton, Pa., being added to its already large iron plant. The converting works were built by Mr. A. L. Rothman, Mr. Holley acting as consulting engineer. The former gentleman started the works on October 23d, 1875, and remained in charge until May, 1876, when he was succeeded by Mr. George F. Wilhour, who obtained his Bessemer experience at Johnstown, Pa. The blooming mill was built from Mr. Holley's plans, under the

supervision of Mr. W. W. Scranton, the general superintendent of the company, and has all the late improvements.

The Vulcan Iron Company, of St. Louis, Mo., has their converting works and blooming mill nearly ready to start, they being an addition to its already large iron mill and extensive blast-furnaces. Mr. Holley has furnished the plans and Mr. D. E. Garrison, the general manager of the company, has had immediate charge of the erection, Mr. John Hogan being his assistant. When these works start there will be in operation eleven 5-ton plants with 22 vessels, capable of turning out, in the aggregate, 550,000 gross tons of ingots per year.

Having enumerated the various Bessemer works according to the order in which they started, and in so doing having referred to the wonderful increase in product, it seems a fitting conclusion to briefly review the causes of such wonderful strides in capacity. As stated, after building the original experimental plant at Troy, Mr. A. L. Holley seems to have appreciated that the manufacture was capable of a development far beyond that which had been attained in those countries in which it was already considered a success.

Even if his mind did not fully realize this conclusion, his mechanical intuition was alive to the possibilities of improvement, and the result of his thought gave us the present accepted type of American Bessemer plant. He did away with the English deep pit and raised the vessels so as to get working space under them on the ground floor; he substituted top-supported hydraulic cranes for the more expensive counter-weighted English ones, and put three ingot cranes around the pit instead of two, and thereby obtained greater area of power. He changed the location of the vessels as related to the pit and melting-house. He modified the ladle crane, and worked all the cranes and the vessels from a single point; he substituted cupolas for reverberatory furnaces, and last, but by no means least, introduced the intermediate or accumulating ladle which is placed on scales, and thus insures accuracy of operation by rendering possible the weighing of each charge of melted iron, before pouring it into the converter. These points cover the radical features of his innovations. After building such a plant, he began to meet the difficulties of details in manufacture, among the most serious of which was the short duration of the vessel bottoms, and the time required to cool off the vessels to a point at which it was possible for workmen to enter and make new bottoms. After many experiments, the result was the Holley Vessel Bottom, which, either in its form as

patented, or in a modification of it as now used in all American works, has rendered possible, as much as any other one thing, the present immense production.

Then he tried many forms of cupolas at Troy, adopting in the original plant a changeable bottom or section below the tuyeres, and developing this idea still further in the first 5-ton works; then later, at Harrisburg, assisting Mr. J. B. Pearse the furnace was improved to a point which rendered these many bottoms unnecessary, chiefly by deepening the bottom and enlarging the tuyere area. Upon his rebuilding the Troy works after their destruction by fire, Mr. Holley put in the perfected cupolas. At this time the practice was to run a cupola for a turn's melting, which had reached eight heats or forty tons of steel, and then dropping its bottom. This was already an increase of one hundred per cent. over his boast about the same amount in twenty-four hours.

The Cambria works were now running, and Mr. Holley had become officially connected with them as consulting Bessemer engineer. Many discussions and consultations took place between Mr. George Fritz, Mr. Holley, and the writer, as to the possibility of increasing the product of the works. Among other things, tapping cinder from the cupolas was thought of, and decided upon. These works had already placed their turn's work at nine instead of eight heats. The Pennsylvania works under Mr. J. B. Pearse's management, followed with an increased production. The Cambria works applied the cinder tap, and the production went up to the unanticipated amount of thirty heats, or one hundred and fifty tons in twenty-four hours. Grand as we thought this, it is only about one-half of the present yield of each of several works. During all this time many details were modified, and as the new ways proved successful they were adopted in the regular practice. I think one thing which had a strong bearing on the increased production was the labor organization of the Cambria works. In compliance with the policy decided upon, I started the converting works without a single man who had ever seen even the outside of Bessemer works, and, with a very few exceptions, they were not even skilled rolling-mill men, but on the contrary were selected from intelligent laborers. The result was that we had willing pupils with no prejudices, and without any reminiscences of what they had done in the old country or at any other works. Of course when one works went ahead, the others had to follow. Mr. George Fritz was the embodiment of push, and with such men to call on as William R. Jones, J. E. Fry, Charles

Kennedy, Alexander Hamilton, and D. N. Jones, his efforts were ably seconded, and Cambria for a long time maintained the lead.

Mr. Z. S. Durfee tried at Wyandotte to fill an ingot mould from the bottom, the steel being poured into the top of an adjoining mould. Upon taking charge of the works, I still further carried out this idea, and later Mr. John E. Fry and myself took out a patent on the process. At about the same time Mr. Holley, at Troy, was elaborating the same idea, and later, at Harrisburg, carried it much further and patented it. After the starting of the Cambria works, the process of bottom casting was fully gone into, and Mr. William R. Jones's improvements, since patented by him, rendered it a complete success. I know that some makers do not fully acknowledge its merits, but it certainly has a right to rank among the prominent features of the American Bessemer practice.

While I am not able to mention all of the very many good things accomplished by the gentlemen at each and all the various works, I am, at the same time, well aware they have all done their share toward achieving the great end; and, fortunately, their mutual relations have been so pleasant, that each one's experiences have been freely imparted to the others. This has done wonders to advance the science. But without one element, all skill and all mechanical talent would have been wasted, and with it nearly all things have been possible. That element has been, and is, "American push."

THE HEMATITE ORE MINES AND BLAST FURNACES EAST OF THE HUDSON RIVER.

BY JAMES F. LEWIS, AMENIA, DUTCHESS COUNTY, N. Y.

THE hematite iron ore mines east of the Hudson River are confined to a strip of country ten to fifteen miles wide, commencing on the south, near Fishkill, running northeast through Dutchess County, and striking the southeast corner of Columbia County, extending into Litchfield County, Conn., known there as the Salisbury mines, cropping out again at and near West Stockbridge, Lanesboro, and Cheshire, Mass., also in Bennington County, Vermont.

The ores are found in beds or deposits and in veins, with a limestone ledge on one side and slate on the other, from six to thirty feet from the surface. Portions of it are quite solid, called rock ore, but

the greater quantity is mixed with ochre, and has to be broken up and washed to fit it for furnace use.

Some of these mines are very old, having been opened from one hundred to one hundred and fifty years. The majority, however, have been developed within the past twenty years. As a rule, the deposits are worked by open mining, the earth being removed from the top. Some of them are provided with machinery for raising the ore in cars on inclined planes, and washing it with Newbould or Bradford washers, while others still hold to the old-time method of drawing it out with horses and carts, and washing in sluice-boxes.

At four of the mines near West Stockbridge they are mining successfully underground, by shafting and running levels. Although the timbering and planking are quite expensive, there are some good reasons in favor of this method of mining hematite ore. It is, however, an open question in this region which is the best and cheapest, open or shaft mining.

The quantity of water in the different mines varies according to their situation, from 25 to 700 gallons per minute.

At the present time, only twenty-two of the thirty-eight mines enumerated in this paper are in operation, employing about one-half their usual force, mining 15,000 tons per month.

Before the panic of 1873 Dutchess County alone produced 164,000 tons per year, 64,000 tons being smelted into charcoal pig iron, and 100,000 tons into anthracite pig, at the furnaces on the Hudson, from Manhattanville to Troy. Columbia County turned out 35,000 tons per year, 28,000 tons being used at the charcoal furnaces, and 7000 tons at the anthracite. The Salisbury mines produced 49,000 tons, all of it being used in Litchfield County for charcoal pig. The Berkshire County, Mass., mines produced 65,000 tons yearly, of which 20,000 tons were used for anthracite iron, and 45,000 tons smelted into charcoal pig; a total of 330,000 tons of hematite ore per year, against 180,000 tons at the present time. The analyses of the ores show from 35 to 53 per cent. of metallic iron. (See Table of Analyses at the end of this paper.)

I. MINES.

1. Dutchess County, New York.

Dutchess Ore Company, situated at Sylvan Lake, sixteen miles east from Dutchess Junction, on the Clove Branch of the Dutchess & Columbia Railroad, Allard Anthony, President, Poughkeepsie,

New York; J. S. Dearing, Treasurer, Fishkill, New York; opened 1872; known as the Horton Mine.

Thirty horse-power engine; two locomotive boilers, 48″ x 20′; one No. 11 Knowles pump; one small pulsometer.

Ores raised on inclined plane in cars; dumped from cars into sluice; carried by water to a Newbould washer; from the washer loaded directly into cars for transportation to the furnaces.

Present capacity per year, 7000 tons.

Fishkill Ore Mine, owned by A. Tower, situated at Sylvan Lake, sixteen miles east from Dutchess Junction, on the Clove Branch of the Dutchess & Columbia Railroad.

Opened 1855.

One engine, 12″ cylinder, 30″ stroke; three tubular boilers, 48″ x 14′; two No. 10 Worthington pumps, 6″ suction; one rod pump, 10″ x 3′.

Ore raised on inclined plane in cars; dumped directly into a Newbould washer, from which it falls into small dump cars, carried about one hundred feet on a tressel-work, and loaded into cars for transportation.

Present capacity, 10,000 tons.

Clove Mine, situated at Unionvale, four miles from La Grangeville Station, on the Dutchess & Columbia Railroad. Owners, A. Tower & Co., Poughkeepsie, New York.

Opened about 1834.

One Wood & Mann 12 horse-power engine, connected with boiler; also one 36″ x 10′ locomotive boiler; one No. 4 Worthington pump, 10″ plunger, 18″ cylinder.

Ore raised from mine with horse-power derrick; drawn in carts about fifty feet to a Newbould washer, from which it goes into carts again, and is drawn to the ore pile to await transportation by wagon to railroad.

Capacity, 8000 tons per year.

Beckman Mine, situated at Beckman, three and one-half miles from Sylvan Lake Station, on Dutchess & Columbia Railroad. Owner, Albert Tower, Poughkeepsie, New York.

Opened 1872.

One sixteen horse-power Novelty engine, 8″ cylinder, 36″ stroke; one locomotive boiler, 36″ x 14′; one flue boiler, 36″ x 20′; one

No. 9 Knowles pump, 7″ suction; one plunger pump, 9½″ x 18″; one Newbould washer.

Ores raised in cars on inclined plane; hoisting drum, 3′ 6″ x 4′ 6″; ore transported in wagons about two and one-half miles to the Clove Branch Railroad.

Capacity, 12,000 tons per year.

NOTE.—The ores from the above three mines are used exclusively by the owners at their furnaces in Poughkeepsie, being mixed with magnetic ores from the Forest of Dean and Lake Champlain Mines.

Sylvan Lake Ore Mine, situated at Sylvan Lake; opened 1868 by Geo. H. Brown; present proprietors, Sylvan Lake Ore & Iron Co., John S. Shultze, President; W. A. Reed, Treasurer.

One forty-five horse-power Novelty engine; three tubular boilers, 48″ x 14′; one No. 5 and one No. 7 Knowles pumps for pumping water from mine; one No. 11 Knowles pump for pumping water from the lake to washer.

The ore is raised in cars on inclined plane with hoisting drum driven by a double oscillating engine, 10″ x 12″; dumped from hoisting house into Newbould washers, from which it runs into small dump cars, carried about fifty feet, and loaded from tressel-work into railroad cars for transportation to furnaces in New York and Pennsylvania.

Capacity, 20,000 tons.

Clove Spring Mine, situated at Unionvale, four miles from La Grangeville Station, on Dutchess & Columbia Railroad.

Opened 1871. Owners, Clove Spring Ironwork Co.; John S. Shultze, President; W. A. Reed, Treasurer.

One forty-five horse-power engine; one locomotive boiler, 48″ x 16′; one tubular boiler, 45″ x 15′; one No. 7 Knowles pump, 6″ suction, 2½″ discharge, for pumping water from the mine; one Worthington duplex pump to pump water from pond to washer, about one thousand feet with seventy feet rise.

Ore is raised in cars on inclined plane one hundred feet long, at an angle of 45°; washed with Newbould washer; transported in wagons three and one-quarter miles to the company's furnaces at Beckman, and smelted into charcoal pig iron.

Capacity per year, 20,000 tons.

Pawling Mine, situated in town of Pawling, one and one-half miles from New York & Harlem Railroad.

Opened 1872 by J. C. Haight. Present proprietors, Pawling Iron Mining Co.; Horace Landen, President, Chapinville, Conn.

There are two openings. The first is worked under a royalty; the other is owned by the company.

The ore is taken from the mine with horses and carts, drawn about one-eighth of a mile, and washed in sluice-boxes. The ore is principally used for making charcoal pig iron.

Present capacity, 10,000 tons.

Squabble Hole Mine, situated in town of Amenia.

Opened 1865. Owners, Peekskill Iron Co., Peekskill, New York; T. F. Wright, President; Hugh W. Adams, Treasurer.

One Bacon hoisting engine, twenty horse-power; one Hughes & Phillips stationary engine, thirty horse-power; two 22′ tubular boilers; one Worthington duplex pump, 10″ x 14″.

Ores raised from mine in cars on inclined plane, then drawn by horse-power three hundred feet from head of incline to Bradford's patent washer. The ore is used by the company in its furnaces at Peekskill.

Capacity, 8000 tons per year.

South Dover Mine, situated at South Dover, one mile from New York & Harlem Railroad. Formerly owned by the Dutchess County Iron Works.

Known as the Foss ore. Smelted in company's furnace, near the mine, into charcoal pig iron. The iron was used by the South Boston Foundry Company in casting heavy ordnance for the government. The mine was recently purchased by the above-named company, and is being fitted up with machinery for shaft-mining.

Gridley Mine, situated at Amenia.

Opened 1825. Owners, N. Gridley and Son, Wassaic, New York.

One fifteen horse-power engine; one tubular boiler, 30″ x 12′; one No. 5 Knowles pump, 4″ suction.

Ore drawn from mine in carts; washed in Newbould washer; transported in wagons two and one-half miles to the company's furnace at Wassaic, where it is smelted into charcoal pig iron.

Capacity per year, 8000 tons.

Amenia Mine, situated at Amenia.

Opened about 1760.

The ore was used at the time of the Revolutionary war for making

guns, being worked in a forge at what is now known as the "Old Steel Works." Formerly owned by Abiah Palmer. Present proprietors, Amenia Mining Company, W. H. Barnum, President, Lime Rock, Conn.

One fifteen horse-power engine; one twelve horse-power engine; one tubular boiler, 42″ x 12′; one locomotive boiler, 48″ x 12′; one Worthington duplex pump, 10″ x 14″; one No. 6 Worthington pump; Bradford washer, three sections.

Ore drawn from mine with carts, transported in wagons one mile to railroad. Used at the company's furnaces in Connecticut.

Capacity, 12,000 tons per year.

Manhattan Mine, situated at Sharon Station, on New York & Harlem Railroad.

Opened about 1780. Owners, Manhattan Mining Company; William Barclay Parsons, President; J. R. Rand, Treasurer, No. 21 Park Row, New York.

One Woodruff & Beach engine, eighty horse-power; one Ryder engine, forty-five horse-power; one twenty horse-power engine, built by Delamater Iron Company; four cylinder boilers, 36″ x 40′; one Root boiler; one Worthington duplex pump, 14″ plunger; one rod plunger pump, 18″ cylinder, 6′ stroke, throwing 16″ column of water one hundred and thirty-five feet perpendicular height.

Ore is raised in cars on inclined plane by two of Reynolds's patent friction hoisters, 5′ drums; washed with Bradford's patent washer, and loaded from it directly into railroad cars for transportation to furnaces. Used with magnetic ores for making Bessemer pig iron.

Capacity, 25,000 tons per year.

Maltby Mine, situated at Millerton, on the line of the Poughkeepsie, Hartford & Boston Railroad.

Opened 1750. C. S. Maltby, New Haven, Conn., proprietor.

One twenty horse-power engine; one No. 6 Worthington pump, 6″ suction; Bradford washer.

Ore drawn from mine in carts, smelted into charcoal pig iron at the furnace of the proprietor, on the premises.

Capacity, 10,000 tons per year.

Riga Mine, situated at Mount Riga, on the New York & Harlem Railroad.

Opened 1865. Incorporated company. John H. Cheever, President, New York City. Leased by the Riga Mining Company; William H. Barnum, President, Lime Rock, Conn.

One forty horse-power engine; one locomotive boiler, 48″ x 14′; one No. 6 Cameron pump, and a Cornish lift pump, 10″ column.

Ore raised from mine in cars on inclined plane, dumped from hoisting house into a Bradford washer, thence taken in carts one hundred feet, and loaded in cars for transportation.

Capacity per year, 10,000 tons.

Eggleston Mine, situated at Mount Riga, on the Poughkeepsie, Hartford & Boston Railroad.

Opened 1873. John H. Cheever, proprietor, New York City.

Shaft mining, 180 feet deep; first level, 80 feet; second level, 150 feet.

One forty horse-power engine, flue boiler; one Cornish lift pump, 6″ column; Bradford washer.

Capacity per year not yet determined, as, owing to the depression in the iron trade, but very little has been mined.

Dakin Mine, situated at Mount Riga, one-half mile from New York & Harlem and Poughkeepsie, Hartford & Boston Railroads.

Opened 1872. Leased on royalty by Dakin Brothers.

Machinery, none.

Ore taken from mine in carts and washed in sluice.

Capacity, 4000 tons per year.

Total capacity of mines in Dutchess County, 164,000 tons per year, 64,000 tons being used for making charcoal pig iron, 100,000 tons for anthracite iron, finding a market along the Hudson River from Manhattanville to Troy. At the present time there is being mined about 10,000 tons per month, of which amount 3200 tons are used for charcoal pig. 6800 tons are sent to the anthracite furnaces in Troy, Poughkeepsie, Hudson, and Manhattanville.

2. Columbia County, New York.

Morgan Mine, situated in the town of Ancram, one and one-quarter miles from the Poughkeepsie, Hartford & Boston Railroad.

First discovered about 1776, by Livingston; not worked, however, until within the past twenty-five years. Leased on royalty by George Williams, Amenia, N. Y.

No machinery at present.

Ore taken from mine in carts and washed in sluice.

Capacity, 7000 tons per year.

Reynolds Mine, situated in the town of Ancram, on the Poughkeepsie, Hartford & Boston Railroad.

Opened 1857. Owners, Ancram Iron Company. Francis A. Palmer, President, New York City. Leased on royalty by James M. Winchell & Son, Millerton, N. Y.

One twenty horse-power engine; one flue boiler, 25′ long; one No. 5 Cameron pump.

Ore taken from mine in carts and washed in Bradford washer.

Capacity, 6000 tons per year.

Weed Mine, situated at Boston Corners, on the New York & Harlem Railroad, near junction of Rhinebeck & Connecticut Railroad and Poughkeepsie, Hartford & Boston Railroad.

Opened about 1780. Owners, Weed Ore Company, Boston Corners; H. M. Whitehead, Esq., agent, No. 55 Wall Street, New York. Geo. Williams, lessee.

One thirty horse-power engine; one No. 4 Knowles pump; one large pump for use of washer; one flue boiler, one tubular boiler, forty horse-power each.

Ore taken from mine in carts and washed in sluice-boxes from washer, taken in cars on inclined plane seven hundred feet, and loaded in railroad cars for transportation.

Capacity, 12,000 tons per year.

Copake Mine, situated at Copake, on the New York & Harlem Railroad.

An old mining property, worked for a number of years. Now owned by Frederick Miles, who has recently developed the mine extensively.

It is fully equipped with steam-power, Bradford washer, Blake crusher, etc.

Ore taken from mine in carts. It is used for making charcoal pig iron at the proprietor's furnace at the mine.

Capacity, 10,000 tons per year.

Total capacity of mines in Columbia County is 35,000 tons per year, 28,000 tons being used for charcoal pig iron, 7000 tons for anthracite pig.

At the present time there are but two mines at work, taking out 1400 tons per month.

Haight Mine, situated at Hillsdale.

Opened in 1862. E. Haight, Treasurer, 18 Wall Street, New York City.

Hillsdale Mine.

Opened 1834. Ore taken from mine by steam-power and carts. Not worked since 1874. Owned by J. B. Ireland, 170 Broadway, New York City.

Mitchell Mine, Hillsdale, New York.

Opened 1800. Owned by S. E. & S. W. Mitchell.

3. Litchfield County, Connecticut.

SALISBURY MINES.

Old Hill Mine, situated at Ore Hill, on Connecticut Western Railroad.

First opened, 1731, by Thomas Lamb. In those days the ore was taken in leather bags on horseback to Ousatonic (now Great Barrington), Mass., sixteen miles, and worked in forges. Formerly owned by Ezekiel Ashley and John Pell. Present proprietors an incorporated company called "The Proprietors of the Ore Bed in Salisbury." Leased on royalty by an incorporated company, P. B. Everts, president.

One fifteen horse-power engine; one tubular boiler, 48″ x 16′; one No. 7 Blake pump, 6″ suction; Bradford washer, three sections.

Ore taken from mine in carts. Used at the different furnaces in Litchfield County for making charcoal pig iron.

Capacity, 20,000 tons per year.

Chatfield Mine, situated at Ore Hill, on the Connecticut Western Railroad.

Opened 1740. Formerly owned by Philip Chatfield. Leased on royalty by Barnum, Richardson Company.

One fifteen horse-power engine; one tubular boiler, 48″ x 16′; one No. 7 Worthington pump, 7″ suction; Bradford washer, three sections; one Blake crusher.

Ore taken from mine in carts, and transported in wagons to company's furnaces, and smelted into charcoal pig iron.

Capacity, 10,000 tons per year.

Porter Mine, situated at Lakeville.

Opened 1776, by Doctor Joshua Porter.

Not worked extensively until the past ten years.

Present proprietors, the heirs of J. M. Holley. Leased on royalty by P. W. Lippett & Co.

One eighty horse-power engine; one locomotive boiler, 36″ x 12′; one No. 10 Knowles pump, 6″ suction.

Ore taken from mine in carts, washed in a Newbould washer, and used at the charcoal pig iron furnaces in Litchfield County.

Capacity, 4000 tons per year.

Davis Mine, situated at Lakeville.

First opened about 1732, by Thomas Lamb. Present proprietors an incorporated company. Leased on royalty by a company known as the "Davis Digging Company," W. H. Barnum, President.

One thirty horse-power engine; one tubular boiler, 48″ x 16′, built by Pacific Iron Works, Bridgeport, Conn.; one Worthington duplex and one Worthington No. 7 pump; Bradford washer, four sections; Blake crusher, 9″ x 15″, run by a fifteen horse-power Utica engine.

Ore taken from mine in carts, used at Barnum, Richardson Company's furnace.

Capacity, 15,000 tons per year.

Total capacity of the Salisbury mines, per year, is 49,000 tons, all of it being smelted into charcoal pig. At the present time the mines at work are turning out 3000 tons per month.

Kent Mine, Kent, Conn., Kent Iron Works, proprietors. B. Eaton, President, John Hobson, Treasurer.

Opened about 100 years ago.

Open mining. The company is at present sinking a shaft, and putting in machinery to mine underground.

The ore smelted into charcoal pig iron in furnace owned by the company.

Peet Mine, East Canaan, Conn. Owned by Geo. Peet. Recently opened. Not worked at present. All indications show an extensive deposit of ore.

4. Berkshire County, Massachusetts.

Hudson Iron Company, situated near West Stockbridge, on a

branch of the Boston & Albany Railroad. J. W. Hoysradt, President and General Agent; S. Seymour, Secretary.

Opened in 1852 by the old Stockbridge Iron Company.

Three shafts, 150 feet deep, with three levels or stories, being strongly timbered to prevent caving. The mine is equipped with three Worthington duplex pumps, steam cylinder, 28½″, plunger 10¼″, stroke 12″; two twenty-five horse-power engines; four boilers 3′ x 30′.

The ore is raised in buckets, with drum 2½′ diameter, 4′ long; washed in a sluice; transported by railroad to the company's furnace at Hudson; mixed with magnetic ores and smelted into anthracite pig iron.

Capacity, 14,000 tons per annum.

Leet Mine, situated near the above.

Opened before the Revolutionary war, the ore being taken to the Mount Riga Forge in New York State. Owned by the Stockbridge Iron Company. Leased to the Richmond Iron Works. W. H. Barnum, President; George Church, Treasurer and General Manager.

Shaft 150 feet deep, with seven levels. Formerly worked in open mine until it became so deep that it was not profitable to remove the earth.

One No. 8 and two No. 6 Cameron pumps; two flue boilers, 36″ x 28″ and 40″ x 16′.

Ore raised in buckets with Bacon hoister; washed in Bradford washer, run by an engine 8″ x 20″.

The ore is taken to the company's furnaces at Richmond and Van Deusenville; smelted into charcoal pig iron.

Capacity, 15,000 tons per year.

Cone Mine, on the same vein of ore, in the town of Richmond. A very old mine, owned by John H. Cheever of New York, leased to the Richmond Iron Works. Worked in open mine until within three years. At present time has one shaft 70 feet deep; one level; one No. 5 Cameron pump in the mine; the shaft being sunk from the bottom of the open mine, it is necessary to run one No. 5, and one No. 6 Worthington pump to raise the surface water. Boiler capacity for 50 horse-power; two flue boilers, 5′ x 26′ and 3′ x 21′; one tubular boiler, 42″ x 24′.

Ore raised in buckets, drawn in carts three-quarters of a mile, and

washed in Bradford washer; smelted at the company's furnace into charcoal pig iron.

Capacity, 8000 tons per year.

Cheever Mine, situated two miles northeast of the company's mine, owned by John H. Cheever; leased to the Richmond Iron Works.

The largest mine in this section of country, showing a large deposit of rock ore, making it necessary to use but a small quantity of timber.

Four shafts, 150 feet, running seven levels from 150 feet to 500 feet long; three No. 6 Cameron pumps; two flue boilers, 36″ x 28′ and 40″ x 16′.

Ore raised in buckets with Bacon hoister, washed in Bradford washer; smelted into charcoal pig iron in the company's furnaces at Richmond and Van Deusenville.

Capacity, 30,000 tons per year.

Goodrich Mine, West Stockbridge.

Opened 1875. Leased by A. Van Arsdale, No. 111 Broadway, New York.

Shaft mining 116 feet deep, two levels; one No. 5 Blake pump, 5″ suction, $3\frac{1}{2}$″ discharge; one locomotive boiler, 48″ x 16′; one 60 horse-power engine, 10″ x 30″.

Ore raised in buckets; washed in sluice.

Mine not fully developed. Estimated capacity, 8000 tons per year.

Cook Mine, Richmond.

Opened 1873. Owned, with farm of 140 acres, by A. Van Arsdale, No. 111 Broadway, New York.

Not developed.

Bacon Mine, Richmond.

Opened 1846. Bacon & Andrews. Leased to the Pomeroy Iron Works, West Stockbridge; W. M. Kniffin, Agent.

This company has another mine, known as the Andrews Mine, opened in 1871.

Branch Mine, Richmond.

Opened 1856. William Branch, proprietor.

Not developed.

Lovelace Mine, two miles north from Richmond Station.

Opened in 1866, by Walter A. Lovelace.

Not worked very extensively. Said to be very rich in manganese. Analysis shows metallic manganese, 14.662 per cent.

Lanesboro Mine, two miles west from Lanesboro.

Opened 1856. J. C. Colby, Pittsfield, Mass., proprietor.

Open and shaft mining; No. 5 and No. 6 Cameron pumps, with plunger pump in shaft; tubular boiler, 48″ x 16′; one flue boiler nearly one hundred years old, tested in 1873, with pressure of 200 pounds, hydraulic pressure.

Ore washed in sluice; smelted into charcoal pig iron at Lanesboro, in furnace owned by J. C. Colby.

Bliss Mine, Cheshire.

First opened in 1782, and the ore worked in a forge. Reopened in 1872. Operated by Messrs. Burget & Perry.

Said to be very rich, parts of it yielding 62 per cent. metallic iron.

There are other old mines in Cheshire, known as the Brown and King beds, not now in operation.

5. Vermont.

Henry Mine, H. Burden & Sons, Troy, New York.

A very large deposit of ore located three miles south of North Bennington.

Opened about 1845.

The ore is very rich, easily smelted, and makes a superior quality of iron.

When in operation, there were taken from this mine 20,000 tons per year.

Bennington Mine, H. Burden & Sons, Troy, New York.

Opened 1845. Two miles east from Bennington, on the Bennington & Glastenbury Railroad, with extensive water-power and machinery for pumping and raising ore.

This ore is also rich and easily smelted, containing manganese, veins of pure oxide of manganese being found between the strata of ore.

Capacity, about 15,000 tons per year.

When in operation, the ores were mixed with magnetic ore and smelted into anthracite pig iron in the company's furnace at Troy.

6. Maine.

Katahdin Iron Works, O. W. Davis, Jr., Bangor, Maine.

Mine is located in Katahdin, 50 miles northwest from Bangor, on Pleasant River, a tributary of the Piscataquis.

The ore is limonite, derived from the decomposition of a micaceous, pyritiferous, syenitic ledge, which seems to be upthrown through the overlying mica schist and slate rocks. A part of the ore comes from the simple wearing away of the ledge itself by the action of the elements, while a part is a precipitate of iron oxide that has been taken up in solution by the water of springs coming through the ledge, and deposited on the side of the hill. The ore is very abundant, covering many acres to the depth of three to twenty feet.

The iron made from the ore is very free from sulphur and phosphorus.

II. BLAST FURNACES.

1. Dutchess County, New York.

Clove Spring Iron Works, John S. Shultze, President; W. A. Reed, Treasurer; Crocker Brothers, No. 32 Cliff Street, New York, Agents.

Furnaces at Beckman, four miles from Lagrangeville, on the Dutchess & Columbia Railroad.

Two stacks, 32 x 9 and 35 x $9\frac{1}{2}$; built 1830 and 1873. Diameter of hearth, 2′; two 3″ tuyeres. Warm blast; temperature 180°; pressure one pound. Stack No. 1, driven by water power, 16′ overshot wheel, 10′ head; two blast cylinders 50″ diameter, 5′ stroke. Stack No. 2, driven by steam-power; one blast cylinder, iron, 3′ diameter, 3′ stroke; two cylinder boilers, 30″ x 48′.

The ores used are brown hematite from the Clove Spring Mines. The iron is used for car-wheels, malleable and gun castings.

Tensile strength, 32,000 to 37,000 pounds. Annual capacity, 7000 tons.

Wassaic Furnace, N. Gridley & Sons, proprietors, Wassaic, Dutchess County, New York.

Built in 1826; put in blast in July of same year. The first 200 tons of iron made were sold to G. Kimball, of the West Point Foundry, and carted by teams across the country.

Rebuilt in 1863, of slatestone, 32 x 9, with small hot-blast dome on top. Four tuyeres, $2\frac{3}{4}''$ diameter.

Water-power, overshot wheel, 20′ diameter, with 6′ head.

The iron is used for car-wheels, chilled rolls, malleable castings, ordnance, and machinery castings that require great strength.

Tensile strength (test made by South Boston Iron Company), No. 3, 28,467 pounds. Annual capacity, 3000 tons.

Ores from the Amenia and Pawling Mines.

Millerton Iron Company, Millerton, New York, W. H. Barnum, President; Walter Phelps, Secretary and Treasurer.

Built in 1855; rebuilt in 1862. One stack, 32 x 9. Diameter of hearth, 40″; 4 tuyeres, $3\frac{1}{4}''$; hot blast, temperature, 400°; pressure $\frac{5}{10}$ lb. Two blowing cylinders, $3\frac{1}{2}'$ stroke, driven by 30 horse-power engine; two 30′ boilers.

Ores from the Salisbury and Amenia Mines.

Iron used for car-wheels and malleable castings.

Tensile strength, 30,000 to 32,000 pounds. Annual capacity, 3500 tons.

Phœnix Furnace, Millerton, C. S. Maltby, New Haven, Conn.

Built 1840; rebuilt 1865. One stack, 32 x $9\frac{1}{2}$; 4 tuyeres, $2\frac{1}{2}''$: two blowing cylinders, driven by steam; hot blast.

Brown hematite ores from mine near the furnace owned by C. S. Maltby.

Annual capacity, 3500 tons.

2. Columbia County, New York.

Copake Iron Works, Copake, Frederick Miles.

Built 1872.

One stack, 32 x 9. Steam and water power.

The ores are brown hematite from the proprietor's mine near the furnace, making a superior quality of iron for car-wheels and machinery purposes.

Annual capacity, 3600 tons.

Beckley Iron Works, Chatham Village, George Adams.

Built by James A. Beckley, in 1873.

One stack, 32 x 9; hot blast; leased by the South Boston Foundry Company.

Makes iron for heavy ordnance from brown hematite ores taken from the company's mine near South Dover.

Annual capacity, 3500 tons.

3. Litchfield County, Conn.

Chapinville Furnace, Chapinville, Horace Landen & Co.

Built in 1826, by Chapin & Robins.

One stack, 25 x $8\frac{1}{2}$; diameter of hearth, 30″; two tuyeres, 3″; water-power, 16′ wheel.

Ores from Salisbury and Pawling Mines.

Annual capacity, 2400 tons.

Canaan Furnaces, East Canaan, Barnum, Richardson Company; W. H. Barnum, President, Lime Rock. N. C. Ward, Manager.

Three stacks, built in 1840, 1847, and 1872.

Nos. 1 and 2, 32 x 9; No. 3, 35 x $9\frac{1}{2}$; diameter of hearth, 40″; four tuyeres, each $3\frac{1}{4}$″; hot blast; temperature 475°; pressure, No. 2, $\frac{9}{16}$, and No. 3, $\frac{6}{10}$ lb. Blowing cylinders, 6 x 6. Average number of tons per week, stack No. 2, 77 tons; No. 3, 84 tons.

Ores from the Salisbury and Amenia Mines.

Iron used for car-wheels, malleable and gun castings.

Tensile strength, from 30,000 to 35,000 pounds. Annual capacity, 12,500 tons.

Stack No. 1 not in blast.

Cornwall Bridge Iron Company, Cornwall Bridge, W. H. Barnum, President.

Built in 1833.

One stack, 32 x 9; hot blast; water-power.

Hunt Lyman Iron Company, Huntsville, Moses Lyman, President; W. H. Barnum, Treasurer.

Built in 1847.

One stack, 32 x 9; diameter of hearth, 40″; hot blast; water-power.

Annual capacity, 3500 tons.

Lime Rock Iron Works, Lime Rock, Barnum, Richardson Company, W. H. Barnum, President; Miles Richardson, Secretary and Treasurer.

Built in 1864.

One stack, 32 x 9; diameter of hearth, 40″ at bottom, 36″ at top; four tuyeres, $3\frac{1}{4}$″; hot blast; temperature, 550°; pressure, $\frac{6}{10}$ lb. Two cylinders, 5 x 6; water-power.

Ores from the Salisbury Mine.

Annual capacity, 3500 tons.

This company has a large machine shop and car-wheel foundry, casting car-wheels for the American, French, German, English, and South American markets.

Sharon Valley Iron Company, Sharon Valley, W. H. Barnum, President; C. W. Barnum, Treasurer.

Built ——; rebuilt 1863.

One stack, 31 x $9\frac{1}{2}$; hot blast; water-power.

Annual capacity, 3500 tons.

Kent Iron Works, Kent, B. Eaton, President; John Hopson, Treasurer and General Manager.

Built in 1826; rebuilt 1846; again in 1870.

One stack, 32 x 8; diameter of hearth, 26″; two tuyeres, $3\frac{1}{4}$″; two blast cylinders, 5 x 6; hot blast; water-power.

Ores from mine owned by the company.

Iron used for machinery and malleable castings.

Annual capacity, 2800 tons.

4. Berkshire County, Mass.

Cheshire Furnace, Cheshire; Richmond Iron Works, Richmond, W. H. Barnum, President; George Church, Treasurer; R. A. Burket, Agent.

Built in 1850, of brick, one stack, 36 x 9; rebuilt in 1866, with stone, 32 x 9.

Double hot blast, Gifford pattern; two cylinders, 5 x 6, driven by steam power.

Ores from the company's mine at Richmond.

Product, car-wheel and machinery iron.

Annual capacity, 3500 tons.

The company has, connected with their works, fourteen charcoal kilns large enough to burn 45 cords of wood each.

Lanesboro Iron Co., Lanesboro, four miles north from Pittsfield, J. H. Colby, proprietor, Pittsfield.

Built in 1847.
One stack, 42 x 11.
Ores from the Lanesboro mine.
Annual capacity, 3500 tons.

Lenox Iron Works, Lenox Furnace, leased by Taylor, Church & Coffing.
Built in 1780, rebuilt in 1839.
One stack, 32 x 9; diameter of hearth, 40″; four tuyeres, 3″; warm blast; water-power; 12′ breast wheel.
Product, car-wheel iron.
Annual capacity, 3000 tons.

Richmond Furnace, Richmond, Richmond Iron Works, W. H. Barnum, President, George Church, Treasurer and General Manager.*
Built in 1830, rebuilt in 1864.
One stack, 32′ 8″ x 9′ 6″; diameter of hearth, 40″; height, 5′ 6″; five tuyeres, 3″; warm blast, temperature, 250°; pressure, ¾ lb.; two cylinders, 5 x 6; steam-power, 40 horse-power Woodruff & Beach engine; two cylinder boilers, 30″ x 36′.
Annual capacity, 3500 tons.
Product sent to Ramapo Car-wheel and Machinery Works.
The company has connected with its furnace three large ore mines and six coal kilns; also four kilns in town of Becket, six in Hancock, and four in Vermont.

Van Deusenville Furnace, Van Deusenville, Richmond Iron Works.
Built in 1834, rebuilt in 1857.
One stack, 30 x 9; diameter of hearth, 20″; four tuyeres, 3¼″; warm blast; temperature, 300°; pressure, 1 pound; four cylinders, 5 x 6; steam and water power.
Annual capacity, 3750 tons.

Pomeroy Iron Works (Anthracite Furnace), West Stockbridge, W. M. Kniffen, General Agent.
Built by Berkshire Iron Company in 1850.
Purchased by Cone Iron Works in 1863, by present owners in 1868; burned and rebuilt in 1872.
One stack, 50 x 14; diameter of hearth, 5½′; open front, open

* The Richmond Iron Works elected, in 1877, J. H. Coffing, President; W. H. Barnum, Treasurer; M. H. Robins and R. A. Burket, Managers.

top; three tuyeres, 4″; hot blast, temperature, 750°; average pressure, 4 pounds; steam-power; two iron blast cylinders, 5 x 5; hoisting engine, 20″ cylinder; four cylinder boilers, 3½′ x 50′.

Ores, Port Henry magnetic, ⅓, and Berkshire County hematite, ⅔.

Iron used in machinery and mowing machines.

Mr. Corliss, of Providence, R. I., put 200 tons in the Centennial engine.

Tensile strength in several trials at South Boston, 21,000 to 28,300 pounds.

Annual capacity, 9300 tons.

5. Vermont.

Pittsford Furnace, Pittsford, Rutland County, J. Prichard.

Built in 1844.

One stack, 40 x 10; hot blast; water-power.

Annual capacity, 3500 tons.

Product, car-wheel and other foundry iron and Vermont spiegel.

Shaftsbury Iron Works, South Shaftsbury, Bennington County, George W. Sweet & Co., lessees.

Built in 1863.

One stack, 30 x 9½; cold blast; water-power.

Annual capacity, 3000 tons.

6. Maine.

Katahdin Iron Works, O. W. Davis, Jr., Treasurer and Manager, Bangor. Furnace at Katahdin Iron Works in Piscataquis County.

Built in 1846, rebuilt in 1874.

One stack, recently enlarged from 35 x 9 to 50 x 9½; four tuyeres; fire-brick hearth, bell and hopper, with hot blast of Gifford pattern, with large combustion-chamber, altered to suit closed top; Whittier elevator; water-power.

Annual capacity, 6000 tons.

The furnace is supplied with limonite ore obtained near the works. The iron is very free from sulphur and phosphorus, and is in demand for Bessemer and crucible steel, malleable castings, and machinery, car-wheels, and for wire-drawing.

In the following table are given the analyses of the ores of the various mines mentioned in the paper as far as they could be obtained.

ANALYSES OF HEMATITE ORES EAST OF THE HUDSON RIVER.	ANALYST.	Sesquioxide of Iron.	Protoxide of Manganese	Sesquioxide of Manganese.	Manganese	Alumina	Lime.	Magnesia.	Lime and Magnesia	Silica.	Quartz, Silica, or Insoluble residue.	Sulphur.	Phosphoric Acid.	Phosphorus.	Carbonic Acid.	Organic matter and water.	Water.	Metallic Iron.
DUTCHESS COUNTY, N. Y.																		
Dutchess Ore Company,	C. F. Chandler,	76.93		2.67		1.08	0.38	0.43		4.73		0.07	0.20	0.09			13.70	53.85
Fishkill Mine,	Chemist of J. A. Griswold & Co.,	72.20		0.56		3.06	trace	0.20		13.75		0.09	0.14	0.06			10.15	50.54
Clove Mine,	S. Dana Hayes,	70.01		1.08		3.20			1.40		12.40	0.18		0.28		11.40		49.00
Beekman Mine,	S. Dana Hayes,	74.56			trace.				6.10		8.10	0.11		0.08		11.20		52.19
Sylvan Lake Mine,	C. F. Chandler,	73.87		0.76	0.53	1.45	0.65	0.38		11.68		0.28	0.176	0.077			10.76	51.71
Pawling Mine,	C. F. Chandler,	69.00		0.10	0.06	2.33	0.44	1.95		12.84		0.03	0.39	0.17			12.52	48.30
Gridley's Protocarb Mine,	J. B. Britton,		1.90			1.47	0.61	0.45					0.30	0.13	24.87			46.06
Gridley's Hematite Mine,																		40.00
Amenia Mine,	Chemist of Barnum, Richardson Co.,				0.576							0.69		0.102				51.41
Manhattan Mine,	F. W. Dahne,	72.40		0.64		6.51	0.91			13.20		0.34		trace.	0.71		4.91	50.68
Riga Mine,	Chemist of Barnum, Richardson Co.				0.375							0.68		0.130				47.78
Dakin Mine,	J. B. Britton,									13.14			.205	0.088				48.70
COLUMBIA COUNTY, N. Y.																		
Morgan Mine,	Chemist of Millerton Iron Company,	61.77		1.65		2.08	0.17	0.07			22.04	none.	1.40	0.61		0.09	10.78	43.24
Reynolds Mine,	Chemist of Millerton Iron Company,	60.41		0.44		0.74	0.22	0.06			27.83	0.006	0.284	0.124		0.39	9.92	42.29
Weed Mine,	J. B. Britton,											0.005		0.214				50.32
Copake Mine,																		48.90
Mitchell Mine,																		50.00
Haight Mine,																		42.00
LITCHFIELD COUNTY, CONN.																		
Old Hill Mine,	Chemist of Barnum, Richardson Co.,				0.958							0.082		0.014				53.00
Chatfield Mine,	" " " "				0.576							0.048		0.219				54.70
BERKSHIRE COUNTY, MASS																		
Hudson Iron Co.'s Mine,	Chemist of Pomeroy Iron Works,	60.97		0.44			0.20			27.06		0.03	0.70	0.81			10.39	42.67
Leet Mine,	" " " "	65.60		7.31			0.09			14.80		trace	0.38	0.17		11.82		45.92
Cone Mine,	" " " "	78.08		1.14			0.56			5.40			0.07	0.03		6.95		54.66
Cheever Mine,	" " " "	55.93		1.38			0.27			30.35		trace.	0.84	0.37		11.23		39.15
Bacon Mine,	" " " "	67.25		6.38			0.67			14.10		trace	1.66	0.73		9.64		47.07
Lovelace Mine,	" " " "	46.22		17.94	12.45		0.32					trace		0.642				32.36
Bliss Mine,	" " " "	64.08		6.15		0.83				16.24		0.16	0.77	0.34		11.62		44.85
BENNINGTON COUNTY, VT																		
Henry Mine,	C. F. Chandler,	73.15	*2.312			3.958	0.725	0.462		5.244		0.050	0.560	0.240			13.333	51.21
Bennington Mine,	" "	44.07		†29.51		4.83	0.42	0.21		9.54		trace	0.44	0.19			9.86	30.85
PISCATAQUIS COUNTY, ME																		
Katahdin Mine,	J. B. Britton,	75.95				0.07	0.16			0.17		0.69		0.06			22.34	53.17

* Traces of nickel and cobalt.

† Binoxide of manganese, also 0.13 oxides of nickel and cobalt.

THE MINERAL WEALTH OF JAPAN.

BY HENRY S. MUNROE, E.M., PROFESSOR OF GEOLOGY AND MINING IN THE IMPERIAL UNIVERSITY OF TOKIO, JAPAN.

THE earliest accounts we have of Japan represent the country as having great mineral wealth, especially of precious and useful metals. Marco Polo, the Venetian traveller, in the thirteenth century, writes of "Zipangu:" "They have gold in greatest abundance, its sources being inexhaustible. The king does not allow of its being exported. To this circumstance we are to attribute the extraordinary richness of the sovereign's palace. The entire roof is covered with a plating of gold. . . . The ceilings of the halls are of the same precious metal; many of the apartments have tables of pure gold of considerable thickness, and the windows also have golden ornaments." Marco Polo also gives an account of an unsuccessful Tartar expedition against Japan, prompted by the supposed great wealth of the country. Columbus also, as well as many other explorers, were attracted and encouraged by these prevalent reports of the wealth of the islands of Zipangu. Kaempfer, writing in 1727, speaks of the great mineral wealth of Japan, and especially of the abundance of gold, which, he says, is found in many provinces.

The Portuguese and Dutch, while they had trading-posts in Japan, furnished tangible evidence of the truth of the early reports. Between 1550 and 1639 the Portuguese merchants sent home from Japan nearly three hundred million dollars' worth of bullion, most of which was gold. As the relative value of equal weights of gold and silver was then six to one, while in Europe, at the same time, it was nearly twelve to one, the exchange of silver bullion for gold was by no means an unimportant part of their business. After the Portuguese, the Dutch continued the exportation of bullion, and the exchange of silver for gold, though with less profit, as the relative value of gold increased with the demand. Between 1649 and 1671 the Dutch traders sent home over two hundred million dollars in bullion, of which, however, nearly two-thirds was silver.

In 1671 the Japanese government, alarmed at the rapid rate at which the precious metals were leaving the country, issued an edict forbidding the exportation of gold or silver, under heavy penalties, which had the immediate effect of stopping this trade.

Besides bullion, copper formed at this time a most important article of export. According to Dr. Geerts,* who has examined the old

* Transactions Asiatic Society of. Japan, vol. iii, p. 41.

books of the Dutch factory in Nagasaki, between 1609 and 1858 about 280,000 tons (of 2000 lbs.) were exported by the Dutch, and during the same period over 250,000 tons by Chinese merchants.

According to Japanese historians, the arts of mining and metallurgy were introduced from China, probably through Corea, toward the close of the seventh century. The following dates are given on the authority of Dr. Geerts, but some at least are open to doubt.

667 A D —Silver first discovered in Japan.
674 A D.—Silver smelting works established.
*684 A D.—Copper first discovered in Japan.
*706 A D.—Copper coins first made.
749 A.D.—Gold first discovered in Japan.

Long before this time, however, the arts of mining and metallurgy must have reached a high state of development, for copper swords and spear-heads, copper tools of various kinds, and specimens of a very peculiar form of copper bell, are frequently found buried in the earth. If the statements of Japanese antiquarians concerning these articles be accepted, they must certainly be regarded as very ancient, possibly belonging to a prehistoric age of copper, but certainly antedating the years given above by many centuries. I have in my possession a large copper bell of this kind, which I hope to exhibit to the Institute at some future time.

But to return to historic times. Until the advent of foreigners the processes in use were very rude, and the production of metals very small. The history of Japanese metallurgy really dates from about the year 1600 A.D., when copper was first smelted on a large scale. The production of gold, probably from easily worked placer deposits, reached its maximum earlier, during the latter half of the sixteenth century; while silver, requiring greater metallurgical skill, was produced in largest quantity about the middle of the seventeenth century. Owing to various causes, which will be fully discussed hereafter, the production of precious metals has gradually fallen off, so that the present annual yield is comparatively small. The amount of copper now produced is about the same as the average of former years, showing little increase or decrease.

Kaempfer, in 1727, enumerates, in addition to gold, silver, and copper, the following as the mineral products of Japan, viz.: sulphur, iron, tin, coal, salt, agates, jasper, and naphtha. This list, with few additions, is nearly the same as we would give to-day. With respect

* Official Catalogue, Japanese Section, Philadelphia Exhibition, p. 49. According to Dr. Geerts, 698 A.D. and 708 A.D.

to the production or exportation of these minerals in former times we have no reliable information, but the amounts produced or exported must have been insignificant.

Past history, though making a very creditable showing of wealth, does not warrant the prevalent belief in the extraordinary mineral riches of the Japanese Islands, unless we suppose that the greater part of these riches are as yet undiscovered, and that more thorough exploration will greatly increase the number of valuable mines. The large amounts of gold, silver, and copper exported from Japan in past years are thought by many to be only a tithe of the possible yield under more advantageous circumstances. Japan is even now looked upon as an "El Dorado," waiting the advent of a more energetic people to yield her enormous riches. To-day foreign capitalists are anxiously awaiting the time when Japanese mines shall be opened to them, and are impatient of the restrictions of the government, which prevent them from developing the great resources of the country to their profit.

The Japanese, however, are very close observers of nature, and make good prospectors, and in the centuries since their attention was first turned to mineral deposits, they have left little or no ground unexplored, while in the mining districts every hill is riddled with tunnels and adits. It seems probable that the gold, silver, and copper of previous years have been derived from a large number of poor deposits, worked by very cheap labor; and most of these old mines cannot now be worked, owing to the increasing value of labor, and to a real and practical exhaustion of most of the deposits. Improved methods of mining are much needed, and will undoubtedly, if successfully introduced, increase largely the product of the mines.

Within the last few years the Japanese government has done much to encourage mining industry, and to determine the real value of the mineral deposits of the country. Foreign engineers and scientific men have been permitted to travel through the country, even when all others were excluded. The island of Yesso has been made the subject of several geological surveys and reconnoissances. Foreign mining engineers have been employed by the government and by private enterprise to examine and report upon mines and mineral lands in other parts of the country. The government has also established a "Mining Office," under the direction of competent foreign engineers, having charge of the government mines, many of which are now worked by the most approved foreign methods, with foreign machinery, and under the control of resident foreign engineers.

Much, however, remains to be done. The great want of the country is for a thorough and systematic geological survey, in the broadest sense of that term; a survey which shall not only map out the topographical and geological features of the country, determine the age and thickness of its formations, but also take an inventory, as it were, of its mineral wealth, determine the boundaries of its mining districts, and the extent and value of the deposits of each; determine where further exploration should or should not be made, and collect into one repository the information already obtained by other explorers.

In the present paper I propose to show what has been learned with regard to the real mineral wealth of the country, and how much has been done towards a thorough and systematic development of the country's resources. For this purpose I shall supplement my own notes, the result of over three years' residence and travel in the country, with a free use of much that has been published on the subject, and of unpublished data and statistics furnished by friends, and derived from Japanese sources.

GEOLOGY OF JAPAN.

As an introduction to an account of the mineral wealth of Japan, it will be necessary to give some idea of the geology of the country. Reserving for another time and place a more elaborate description of the different rock formations, with their characteristic fossils, geographical distribution, and stratigraphical relations, I will attempt at present only a brief sketch of the subject.

The different strata of the Japanese Islands may be classed as follows, beginning with the most recent:

Formation.	Approx. thickness.
1. *Alluvium and terrace formations*,	10 to 85 feet.
2. *Volcanic rocks*, in veins and erupted masses (mostly Basalts),	50 to 500 "
3. *Clay rocks and pumice tufas* (Toshibets Group of the Yesso Survey),	2000 to 2300 "
4 *Shales and sandstone* (Chingkombe group of the Yesso Survey),	1000 to 1800 "
5. *Volcanic rock*, in erupted masses (Andesites and Trachytes),	3000 (?) "
6. *Coal-bearing shales and sandstone* (Horumui Group of the Yesso Survey),	4500 to 8000 "
7. *Volcanic tufas*, and erupted masses of volcanic rock. Porcelain clay rocks of Kiusi, etc, } 8. *Shales and sandstones* (often metamorphic), }	4000 (?) "
9. *Granitic and metamorphic rocks* (Kamoikotan Group of the Yesso Survey),	3000 to 4000 "

The rocks of Japan, as will be noticed, are very largely volcanic; and even those of undoubted sedimentary origin are, with few exceptions, made up wholly or in part of volcanic material. Volcanic force makes itself everywhere manifest in folded and contorted strata, even the most recent rocks being often tilted at high angles. Volcanic action shows itself also in altered and metamorphic rocks, very new formations being represented in many places by slates and quartzites. Japanese coal, though of tertiary age, is rarely found as a lignite, but usually as a true bituminous coal, and sometimes altered to anthracite or graphite.

Volcanic force continues to show itself even at the present day. Volcanoes, active and extinct, are numerous, and hot springs everywhere to be found; while earthquakes are almost of daily occurrence.

The scarcity of fossils in Japanese rocks may perhaps be attributed to the same cause. In the older rocks fossils have disappeared by metamorphic action, and in the later formations the great volcanic activity has retarded or prevented the development of organic life. For this reason it is impossible at present to say just what geological periods are represented by these Japanese strata. The coal-bearing rocks are now believed to be of tertiary age. The overlying rocks are still more recent, many of the fossil shells found therein being of the same species as those now living in Japanese waters. With regard to the age of the underlying strata, below the coal rocks, little or nothing is definitely known. Fossils said to be of carboniferous age, and others said to be Devonian, have been reported; but, so far as I know, descriptions or figures of these fossils have not yet been published.

It is to be hoped that the fossils which were collected in the course of the Yesso Survey, with others since obtained in different parts of Japan, when examined by some competent palæontologist, may furnish more definite information as to the age of these strata.

JAPANESE MINES AND MINING.

As a further introduction to the subject of this paper, it will be necessary here to say a few words about the methods of mining employed in Japan, and the present condition of the mines.

The oldest mines in the country are those worked for gold, silver, and copper; these, with the other metal mines more recently opened, follow, with few improvements, the rude methods of exploitation adopted centuries ago. Coal mining, being of more recent date, has

profited more from foreign teachings, and follows the method of the Western world, so far as it is possible to follow those methods without machinery, and with imperfect tools and appliances.

Method of Attack.—In the metal mines the deposit is usually attacked by an adit on the vein itself; or, in the case of a well-known lode, by a tunnel through the rock. The tunnels are usually constructed for drainage, and are often miles in length, requiring sometimes twenty or thirty years for their completion. To save labor, the airways, slopes, drifts, and exploring tunnels are made extremely small, and often very tortuous, following convenient seams in the hard rock, and choosing always the softest places—in vein or wall-rock, as the case may be. The ore and rock are broken down with picks and wedges. Powder is used only in very hard rock, badly shaped drills and unskilful use of powder making blasting troublesome and expensive.

Stopes.—The stopes are small, and the mine is generally "robbed" of its richest ore first, the poorer material being left in the mine, or taken out only when the miner is forced to it. The peculiar system of administration, by which the miner is allowed almost perfect liberty to select his own working-place, and is paid by the amount of ore or metal produced, encourages this double waste of the miner's labor and of the resources of the mine.

Transportation.—The ore is brought to the surface by the shortest road on the backs of men or women, or dragged out on flat baskets; and the work of these ore-carriers is made doubly hard by the narrow and tortuous character of the passages.

Draining and ventilation are, as a rule, effected by natural means, the lowest adit or tunnel forming the drainage level (*midzunuki*) and the highest the ventilation chimney (*kemuri dachi* or *kasatoshi*). When it becomes necessary to work below the drainage level, a series of rude wooden suction-pumps are fitted up in a special slope, each pump raising the water about six feet and delivering it in a small reservoir or tank at the bottom of the next pump of the series. They are worked by hand, requiring one man to each pump, and can raise but a very small quantity of water, and that only at the cost of much time and labor. When the flow of water becomes large, or the height to which it must be raised great, the mine is abandoned.

Ore Washing.—The ore before smelting is handpicked, and the poorer parts crushed and concentrated by washing. The washing is effected by handjigging on shallow basket sieves of different degrees of fineness. The finest portion, which passes all the sieves, is washed

on a sleeping-table or on the *ita* or shallow washing-board, which is used like our "pan" or the Mexican *batea.*

Coal Mining.—The coal mines are usually worked by a sort of pillar and stall method, the pillars being taken out, as far as possible, in retreating, after the workings have reached the desired extent. The drainage is generally natural, the workings being in the hill-sides, above the level of the streams. In the Karatsu district, one of the most important in Japan, where the hills are very low, and the workings are, for the most part, below water-level, pumping is necessary. Rude wooden pumps, similar to those previously described, are there used; although in some places a drainage shaft fitted with a large bucket, rope, and pulley, and worked by half a dozen or more coolies, is preferred.

The coal mines, like the metal mines, are ventilated by natural means. In some places, where this proves insufficient, attempt is made to increase the flow of air by a rude chimney over the upcast shaft; but as only a small charcoal fire is employed, instead of a furnace, this has but little effect.

The galleries, levels, slopes, etc., are much more regular and of larger size than in the metal mines, and permit better methods of transportation. The coal is usually brought out of the mine on flat baskets hauled by boys. Above ground, packhorses, or two-wheeled wagons propelled by man-power, are used to take the coal to the boats or junks, in which it comes to market.

Present Condition of Japanese Mines.—According to the records of the Mining Office,* there were in 1874 no less than 1856 productive mines in Japan, and in the same year 637 permits to explore for minerals and metals were granted. Of this large number of mines, my own observations led me to believe that not more than four or five per cent. are actively worked; and these few supply sixty to seventy per cent. of the total product of the empire.

The following table gives the mineral product of Japan, for 1874, as estimated by Mr. J. G. H. Godfrey, Chief Engineer of the Mining Office:†

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* Quoted by Mr. Plunkett, Mines of Japan, p. 2.

† Private communication. See also Mines of Japan, p. 5, and Official Catalogue, Japanese Section, Philadelphia, 1876, p. 39.

MINERAL PRODUCT OF JAPAN—1874.

1. Coal, ...	390,000 tons (2240 lbs)
2. Iron, ...	5000 " "
3. Copper, ...	3360 " (2000 lbs.)
4. Lead, ...	207 " "
5. Tin, ...	8.4 " "
6. Silver, ...	312,000 oz troy.
7. Gold, ...	12,000 " "
8 Petroleum, ...	275,000 gallons.

Compared with the yield of the country in the times of the Portuguese and Dutch trade, this table shows a great falling off; particularly in the production of gold and silver. This falling off is mainly due to two causes, viz.:

1. The increased and increasing value of labor.

2. The exhaustion, real or practical, of the richer or more easily worked deposits.

1. The first cause, the rise in the value of labor, is still operative, and can be only partially overcome by labor-saving appliances. In fact, the value of labor has not yet reached its proper level, and will certainly continue to rise for some time to come. This cause alone will prevent most of the abandoned mines from being reopened with profit, even with the aid of the most approved methods of mining.

2. Many of the best mines of the country have been exhausted as far as the lowest natural drainage-level; the workings having been carried to considerable depths, and the life of the mine prolonged to the utmost limit by the aid of long drainage-tunnels, run with great skill, and often requiring the patient work of generations for their completion. These mines cannot now be worked for want of means to get rid of the water, the Japanese pumps and water-buckets being capable of dealing only with small quantities of water and moderate depths.

There are doubtless a number of really valuable mines in the country, particularly of silver and of copper, which, for this cause, either have been abandoned, or are worked on a small scale in the upper levels only. By the use of small mining pumps, driven by steam or compressed air, most of these mines can easily be reopened. By the introduction of better tools, skilled labor, improved methods of mining, and a more rational system of administration, they can be worked with profit. In most cases these mines, if reopened, will not yield large profits, owing to changed conditions and the poverty

of the deposits. There are, however, a few mines which are exceedingly rich, some of which are even now yielding more or less profit, though worked in the most careless and extravagant manner. As a rule, indeed, the richer the mine, the greater the mismanagement. These mines, properly worked, would undoubtedly prove exceedingly valuable.

Much has already been done toward improving the art of mining in Japan. Two members of this Institute, Messrs. Blake and Pumpelly, who visited that country about fifteen years ago, had the honor to introduce the application of powder in mining; and, although the miners have but imperfectly mastered its use, they have been enabled thereby to undertake many works otherwise impossible. Other engineers have since visited Japan; some merely to examine and report upon particular mines or districts, some to open mines and establish smelting works.

The Government Mining Office has under its direction a large number of mines, four or five of which have resident foreign engineers with efficient foreign assistants. In this way large bodies of Japanese miners and furnacemen are being trained, and foreign methods and processes introduced in the most effectual manner. Incidentally, some of these mines have already been made to yield pecuniary profit; eventually, it is expected, all will at least pay expenses. Until within a year or so the mines available for these governmental experiments were, for the most part, those which yielded little or no profit by Japanese methods, the richest mines being under the control of private parties. The temporary losses resulting from the working of these poor mines will, however, be more than balanced by the advantages gained by the introduction of improved mining methods; and when the operations of the Mining Office are extended to the richer mines which have recently come under its control, large pecuniary profits will certainly appear.

All these advantages might, however, be far better attained, and attained at much less expense, by private enterprise. The capitalist, whose fortune is sunk in the mine, demands of the engineer in charge a rigid account of every expenditure; and an economy of working is thus secured which is impossible under the perfunctory supervision of government officers. In conducting experiments and making explorations for private parties, the engineer is forced to feel that economy is of the first importance; and while he is thus fettered to some extent, and often obliged to give up some pet scheme, still the restraint is wholesome, and gives a powerful incentive to careful

thought and well-digested plans of work. Engineers may of course be found who will do as good and as careful work for a government as for private capitalists; but they do this from a sense of duty alone, knowing that their efforts are not likely to be appreciated.

From private enterprise will result economy of working, and therefore increase of profits. Better methods will be selected, and experiments and explorations will be more carefully conducted. The government also, no less than the country at large, may reap direct advantage from the introduction of private capital; for, by a system of royalties, it may obtain revenue as great as, or even greater than, that now realized by working the mines. The capitalist will be amply repaid if he saves and secures the money which under government would have been wasted, and might in some cases safely agree to pay as royalty twice or three times the profits obtained under governmental supervision.

Some means must, of course, be taken in such case to prevent wasteful mining, which is sometimes most profitable, and to secure the safety of the miner, which is often disregarded. With carefully framed laws and occasional governmental inspection these evils may be, in great measure, prevented, and all the benefits of private enterprise secured.

These benefits cannot, I fear, be secured by the use of Japanese capital. If familiar with mining enterprise, the Japanese capitalist usually invests his money in some mine which is yielding a profit by Japanese methods of working; and, even though this profit may be small, he is naturally unwilling to jeopardize it by changing the plan of work for foreign methods with which he is unfamiliar, especially as he sees that most of the government mines, where these foreign methods are employed, are now worked at a loss. And, on the other hand, in case the Japanese capitalist adopts foreign methods, he would in most cases be suspicious of the foreign engineers in his employ, and would harass and hamper them by his want of confidence. Finally, through his ignorance of these new methods of mining, he would be unable to properly check the expenditures, and thus the most important element of success, the oversight and control of the owner, would be wanting.

At present, by the Japanese mining laws, no foreigner is permitted to have pecuniary interest in a Japanese mine, and the governmental permits to explore or mine become null and void if transferred wholly or in part to a foreign capitalist. In view of the objections to governmental mining and to the use of Japanese capital, it would

seem highly advisable that this law should be altered or repealed. The introduction, under proper restrictions, of foreign capital, either alone or, better, associated with Japanese capital, offers the best and cheapest means for realizing the advantages of foreign mining methods, and securing the best services of foreign mining engineers.

A number of Japanese students have been sent abroad to study mining; others are beginning a similar course of study, in their own country, in the Engineering College of the Department of Public Works; and the Department of Education proposes to establish a Mining College, in connection with the University of Tokio. These students, when they finish their respective courses of study, though hardly competent to take charge of large works, will be of great service as assistants to foreign engineers, and at the same time may obtain the necessary practical experience to fit them for positions of greater responsibility. When the mines of the country shall be under the supervision of well-educated and experienced Japanese engineers, the objections to the use of Japanese capital disappear. But this, of course, will not be possible for many years.

JAPANESE COAL-FIELDS.

By far the most important of the mineral resources of Japan, though at present but imperfectly known, and still more imperfectly developed, lies in the large and numerous deposits of coal found in so many parts of the country. Coal occurs in all its varieties—peat, bogwood, lignite, brown coal, bituminous coal, both dry and coking, anthracite, and graphite. Out of the thirty-eight *ken** and *fu* into which Japan proper is divided, coal is found, or reported to occur, in at least thirty-five, anthracite coal in two, bituminous coal in eleven, and lignite in sixteen. In the case of the other six *ken* I have learned, from various sources, the fact of the occurrence of coal, but not as yet its kind.

The following table, based on my own notes and on other sources of information, will indicate something of the extent and character of the more important of the Japanese coal-fields:

* The former division of Japan into provinces (or *shu*) is now retained only in Yesso. The remainder of the empire, excluding three *fu*, or imperial cities, Tokio, Kioto, and Ozaka, is divided into administrative districts, or *ken*. Of these *ken* there were, in October, 1876, thirty-five.

JAPANESE COAL-FIELDS.

Island.	Name of Coal-field.	Estimated area Square miles	Number of workable seams.	Thickness of seams Feet	Est'd thickness of coal. Feet.	Kind of coal
Yesso....	Ishikari Coal-field, upper measures	600	6-12	2 to 19	45	Bitum., dry and coking
" .	Ishikari Coal-field, lower measures. .. .	2400	4	2 to 4	10	" dry coal
" .	Kayanoma Coal-field ..	1	12	2 to 7½	50	" dry and coking
"	Akkeshi Coal-field	...	4	2 to 3	10	" dry coals.
" ..	Iwaki Coal-field .	200	2 +	4½ to 6	10 +	" " "
Nippon	Niigata Coal-field.	.. .	... .	.. .	... .	" " "
"	Kii Anthracite Field .	. . .	.	. .	..... .	Anthracite coal.
"	Awa Coal-field ..	200	. .	.....	.. ..	Bitum., dry and coking.
Shikoku	Chikuzen Coal-field	300	. ..	. .....	.. .. .	" dry coals.
Kiushiu	Karatsu Coal-field, upper measures .	350	3 +	3 to 4	10 +	" dry and coking.
"	Karatsu Coal-field, lower measures.. . .		10	1 to 2	15	" dry coal.
"	Nagasaki Coal-field	2	13?	3 to 16	50	" coking.
"	Miike Coal-field .	25	3?	4 to 8	15	" "
"	Amakusa Anthracite Fields	10	2 +	2 to 3	5 +	Anthracite.

Total area of coal-fields, about ... . 5000 square miles.
Average thickness of coal ... . 15 feet.

The area of the Ishikari coal-fields is calculated on the supposition that the coal rocks are continuous between the Ishikari Valley and the exposures of the same rocks on the south coast. This continuity has not been proved, but seems probable. The area of the Kayanoma fields was determined by actual survey. The areas of the Iwaki, Karatsu, Nagasaki, and Miike coal-fields are estimated from data obtained in visits to these places. The estimated area of the other fields is based on well-authenticated reports of coal at many localities within the assigned limit.

Allowing for fields whose area is yet unknown, and for coal areas not included in the above table, it seems probable that the total area of the coal-fields of Japan is not far from 5000 square miles, as stated above. Assuming that of this area one-eighth only is underlaid by the upper measures, with fifty feet of coal, the average thickness must be at least fifteen feet.

COAL-FIELDS OF YESSO.

The coal-fields of Yesso, probably the most important of Japan, have been very thoroughly explored by Mr. Lyman in the course of the Yesso Survey, but until his final report shall be published we can give but a general idea of their extent and character.

* Including Takashima and other islands in Nagasaki harbor.

There seem to be three areas of coal-bearing rocks in Yesso: the Kayanoma coal-field, the Ishikari coal-field, and the Akkeshi coal-field. Of these the Kayanoma field is small, less than a square mile in area, and the Akkeshi field is unimportant, as containing little or no workable coal. In the Ishikari field are included the Horumui, Sorachi, and other coal regions of the Ishikari Valley, the Makumbets coal to the south, and the Rurumoppe coal of the northwest coast.

It seems probable that this coal-field extends continuously from the southern coast of Yesso, in the province of Hitaka, northward through the province of Ishikari nearly or quite to the northwest coast in Teshio province, a distance of about one hundred and fifty miles, with an average breadth of twenty or twenty-four miles.

The thick seams of coal seem to be confined to the upper measures, and these msasures, constituting the more valuable portion of this large coal-field, are found only in the middle of the island and in the Ishikari Valley. The attention of the survey has been directed chiefly to this portion of the field.

On the Sorachi River there are twelve seams of coal exposed, all but one within a total thickness of three hundred and fifty feet of rock. The upper seam, about five feet thick, is separated from the others by 1200 or 1300 feet of sandstone. The different measurements of these coal-seams show great variation in thickness, perhaps due to the fact that they were made on the outcrops, but probably due to the varying thickness of the beds themselves. The following are the averages of the different measurements given by Mr. Lyman, deducting bony coal and shaly partings in each case, and beginning at the upper coal, viz.: 5.10 feet, 2.75 feet, 18.6 feet, 2.15 feet, 2.10 feet, 3.40 feet, 2.60 feet, 7.00 feet, 2.15 feet, 2.70 feet, 8.70 feet, 7.25 feet; total sixty-four feet of workable coal.* Thickness of measures, five thousand feet; 1500 feet above the upper coal, 1300 feet

* More than one-half of the coal product of Japan is obtained from beds of coal less than two feet in thickness, and seams even less than one foot thick are worked in many places, though yielding a profit only under very favorable circumstances. Mr. Lyman, in his report, assumes three feet as the limit of workable beds, but in view of the above facts this limit seems unnecessarily high. On account of the varying conditions in different parts of the country, and the increasing value of labor, etc., it is impossible to fix the exact limit below which coal-beds become unworkable, but if we take two feet as our standard we shall have abundant margin.

between this coal and the second seam, and about 1800 feet below the 350 feet of production measures.

On the Horumui, 25 miles south of the Sorachi, and still in the Ishikari Valley, these same coals are again exposed, but the beds are neither as numerous nor as thick. Mr. Lyman's section* shows ten seams of coal in about three hundred and fifty feet of rock, of which six only contain good coal of workable thickness, 4.20 feet, 5.00 feet, 2.00 feet, 5.00 feet, 2 80 feet, and 6.90 feet respectively, giving a total thickness of about twenty-six feet of coal.

Near the south coast, in the province of Hitaka, a detailed survey of a portion of this same coal-field was made by the Japanese assistants under my direction, which resulted in finding four coal-seams of workable thickness, 2.3 feet, 2.6 feet, 3.5 feet, and 4 feet (the last reported, not measured). The total thickness of rocks, sandstone, and shales was about 2250 feet, the coal-seams being within 370 feet. According to Mr. Lyman, this section corresponds to that of a portion of the lower coal-measures exposed in the Ishikari Valley. The coal is of inferior quality.

Similar thin beds were found at the northern extremity of the field, near the northwest coast, but the indications there were even less favorable.

Of the three thousand square miles covered by this Ishikari coal-field, about six hundred square miles are known to be underlaid by the upper measures with twenty-six to sixty feet of coal, and it is probable that further explorations may extend this area. The remainder of the field, where the lower measures alone occur, with only three or four thin seams of coal, will prove of little value.

The coals of the upper measures of this field have not as yet been mined, though several tons of samples and specimens have been brought from the different outcrops in the Ishikari Valley. The lower coals have been mined in two places in Hitaka province, near the south coast, but after taking out forty or fifty tons at each place the work was abandoned. These lower coals have not been assayed, but they seem inferior, and probably contain large percentages of ash.

The Kayanoma coal-field is in Shiribeshi Province, on the west coast of Yesso. The area of this field is somewhat less than a square

* Yesso coals, Kaitakushi Reports, p. 7.

mile. The section* given by Mr. Lyman shows twelve seams of fair and good coal of workable thickness, respectively 4.00 feet, 2.67 feet, 5.75 feet, 2.30 feet, 5.68 feet, 3.39 feet, 2.25 feet, 5.80 feet, 1.90 feet, 6.08 feet, 2.60 feet, and 7.40 feet thick. All these seams are contained within less than six hundred feet of strata. The total thickness of workable coal would seem to be nearly fifty feet.

The coal is not so good as that of the Ishikari field, containing usually 6 to 15 per cent. of ash, and in some beds 20 per cent. and more. The water varies from 1 to 11 per cent., being usually between 5 and 8 per cent. It is, however, a bituminous coal, though of poor quality, and not a lignite. One bed furnishes a very fat, long-flaming, blacksmith's coal, while most of the others are steam coals or dry coals with a long flame, a few only being short-flaming.

A mine was opened here about eight or ten years ago, which was for a time under the superintendence of Mr. E. H. M. Gower. The work was interrupted by the revolution, and resumed later under Japanese management. At the time of our visit, in 1873, the mine was producing, if I remember aright, only about fifty tons of coal per week, and this so badly mined as to be mostly slack.

The Akkeshi Coal-field.—At the northeastern corner of the island of Yesso there is a large area of coal-bearing rocks; but coal has been found in only two or three places. Mr. Lyman gives several sections,† the best of which shows ten or more small seams of coal, four of which barely exceed the two-feet limit; and even these are split up into thin benches by thick partings of shale. In other places the showing is even more unsatisfactory; and, as the coal is only of fair quality, this coal-field promises to be of little importance. A small coal mine was opened by the government here in 1871, but abandoned the next year. Like coal from many other parts of Japan, this sometimes contains small beads of amber (?) or some other fossil resin.

COAL-FIELDS OF NIPPON.

Iwaki Coal-field.—On the island of Nippon coal has been found in many places; but with the exception of the Iwaki coal-field on the east coast, we know little or nothing with regard to the extent or character of the deposits.

* Yesso coals, Kaitakushi Reports, p. 6.

† Kaitakushi Reports, 1871–75, pages 411–421.

This coal-field is in the ken of Fukushima and Ibaraki, and about a hundred to a hundred and twenty miles north of Tokio. At the time of my visit, in December, 1874, I estimated its total length at twenty-five to thirty miles in a north and south direction, along the coast, with a breadth of three to five miles, from the coast to the hills of granite and other metamorphic rocks which form its western boundary. This estimate agrees very closely with that given by Mr. Plunkett,* who makes the field thirty miles long by seven broad.

Since the time of my visit coal has been discovered at several places to the north, making it probable that the field is at least fifty miles long. Coal is also reported to occur near Sendai, fifty miles farther north; but, if this be the case, it is probably another basin, and not a part of the same field.

In this coal-field there seem to be but two workable seams, respectively four and a half and six feet in thickness; but a careful survey would, undoubtedly, show many more. The coal is of only fair quality, containing ten per cent. of ash, and about the same amount of water. It does not coke, belonging to the class of dry coals with a long flame. Coal is mined in a small way at several places in this field, and is sent by junks to Tokio, where it is used to a limited extent for steam and household purposes.

Other Coal-fields in Nippon.—North of the Iwaki coal-field there are many small local deposits of lignite, but none of coal. On the west coast, coal is reported to occur in Niigata ken; from which ken I have received specimens both of bituminous coal and lignite. According to Mr. Plunkett, this Niigata coal has been used by the government steamers and at the government gold mines of Sado. The coal is of good quality and abundant; but the limited local demand and the want of a good harbor have so far prevented the development of the mines, and the present production is quite small.

Bituminous coal of good quality is also found in many places near the western extremity of Nippon, and it seems probable that there may be one or more large coal-fields in that region. Anthracite coal of excellent quality, of which I have received several specimens, is found in Miyo ken (province of Kii) at the southern end of Nippon. Captain St. John, of H. M. S. Sylvia, when in the harbor of Katsura, took on board fifty tons of this coal for trial, which he

* Mines of Japan, p. 9; "Shiramisui District."

describes as excellent in appearance, very hard and heavy, and free from dust. Apparently unacquainted with anthracite, he expresses some surprise that this coal, when tested, "simply refused to burn;" when mixed with other coal, however, it did "fairly well."*

COAL-FIELDS OF SHIKOKU.

Awa Coal-field.—Coal is reported to occur in many places on this island; and there is probably a coal-field of some size on the east coast. I have specimens of coal from this region which seems to be of fine quality. One specimen, at least, is of a fat, caking coal. Mr. Frecheville, of the Mining Office, spent the summer of 1875 in exploring this island, of whose mineral resources little is known. His report, however, has not yet been published.

COAL-FIELDS OF KIUSHIU.

The most important coal-fields of Japan, as being best developed and producing most coal, are, at present, those of the island of Kiushiu. These yielded, in 1874, 80 per cent. of the total product of the empire. Last summer, with a party of students, I made a rapid trip through this island, under the auspices of the Imperial University, in the course of which we visited all but one of these coal-fields.

It seems that there are five important fields on this island, which may be styled as follows, viz.: The Chikuzen coal-field; the Karatsu, coal-field; the Nagasaki coal-field; the Miike coal-field, and the Amakusa anthracite fields.

The Nagasaki Coal-field.—The most important of these fields, although of small extent, lies in the harbor of Nagasaki. The available area of this field is not more than a couple of square miles, comprising a few small islands at the mouth of the harbor, and a small strip of the adjoining coast. A vastly greater area lies between these islands, beneath the sea; but it is, of course, doubtful whether any large portion of this can ever be profitably worked. Certain capitalists have the exclusive right to mine coal on three or four of the largest of these islands. Their energies are at present concentrated on one island (Takashima), where they have a large and well-developed mine under English superintendence. In 1874 this mine

* Transac. Asiat. Soc of Japan, vol. iii, part ii, p. 37.

produced over seventy-two thousand tons of coal, averaging two hundred and forty to two hundred and fifty tons per working day. In 1875 the production was increased to between three and four hundred tons per day; and lately the daily output has reached an average of six to seven hundred tons.

There are reported to be thirteen or more seams of coal on this island, three to sixteen feet in thickness. The upper beds have been in former years exhausted by the Japanese, and but three seams are now worked, the "five-feet," and the "eight" and "ten-feet" seams. These last are separated by a parting of shale about one foot thick, and form really one bed, averaging sixteen feet in thickness. Other thick seams are reported, and there is said to be enough coal on the island to maintain a daily production of four or five hundred tons for seventeen years.

Borings have been made on the other islands showing several seams of coal of workable thickness, and the company are now making preparations for the sinking of one or more new shafts.

The coal of Takashima Island is of very fine quality, being a fat, caking, blacksmith's coal, with but five per cent. of ash and one to two per cent. of water. It is the favorite fuel of the various lines of steamers which visit Japanese ports, and the supply by no means equals the demand. In addition to the superior quality of its coal, this Nagasaki field has another great advantage in being situated at the mouth of one of the best harbors in the country. If necessary, large vessels could be loaded with coal at the mouth of the mine. A small navy of junks, and several large hulks and lighters, bring the coal to Nagasaki, adding, however, but little to the cost.

Their situation, of course, gives these mines a great advantage in competition with those of other regions, and could they supply the demand, but very little coal would be mined elsewhere in Japan. Even now the miners of other less favored localities look forward anxiously to the time when, as they say, "the Takashima workings shall be drowned out by the sea."

The coal of the Ishikari region alone approaches the Takashima coal in quality, being in some respects, perhaps, even better; but, as it lies in the interior of the island of Yesso, the expense of bringing it to market, eighty miles by rail, or by river a still greater distance, places it at a serious disadvantage in competition with the Takashima.

Koratsu Coal-field.—North of Nagasaki, on the west coast of Kiu-

shiu, in Nagasaki ken, lies the large coal-producing area which I have styled the Karatsu coal-field, the coal brought from this region being everywhere known as Karatsu coal, though but a small part of it comes from the Karatsu district proper. This field is divided in two places by large and narrow bays, from which many small harbors radiate on all sides. These harbors afford shelter to numerous junks, and facilitate the transportation of coal to market, encouraging the opening of mines at many different points.

In visiting this coal-field I was fortunate in that my road several times crossed the boundaries, so that I am enabled to map the extent, and to approximate very closely to the truth in my estimate of the area of the field. Mr. Godfrey estimates this area at two hundred and sixty-six square miles, dividing it into mining districts as follows:

Imabuku District,	70	square miles.
Taku "	36	" "
Karatsu "	40	" "
Hirado "	120	" "
Total estimated area,	266	" "

From the rough map resulting from my reconnoissance, I am inclined to believe that this is much less than the true area of the field, which I estimate at somewhat over three hundred and sixty square miles, as follows:

Karatsu Peninsula	(including Taku District?),	140	square miles.
Hirado "	(including Imabuku District),	180	" "
Southern "	(including Matsushima),	40 (?)	" "
Total estimated area,		360	" "

With regard to this southern peninsula, I am informed that sandstones, etc., similar to the coal-bearing rocks, are continuous along the west coast nearly to Nagasaki Bay. If these are coal-measures, the peninsula has an area of coal-bearing rocks several times larger than my estimate. No coal has yet, to my knowledge, been discovered here, though large quantities are brought from Matsushima, an island off the coast.

The coal-beds of the Karatsu field are all very thin. In the lower measures there are perhaps ten seams, from one foot or less up to one and eight-tenths feet in thickness. In the upper measures there

are at least two or three workable seams; the best reported at four feet. The thickest that I saw was but two and nine-tenths feet.

Notwithstanding the thinness of the coal-beds this field is vigorously worked, producing in 1874 over one hundred and seventy-six thousand tons of coal, or about forty-five per cent. of the total product of the Empire. Nearly all of this coal was obtained from beds between one and two feet in thickness, while in very favorable situations seams only six-tenths of a foot thick have been worked with profit.

The coal of the Karatsu field is mainly a non-caking dry coal with a long flame, or a caking coal with a short flame. The quantity of ash is sometimes small, but usually ten per cent. or more; and of water not often more than three per cent. Karatsu coal is largely used by Japanese steamers and for manufacturing purposes, being carried by junks to all parts of the country. Its principal consumption, however, is in salt-boiling, being used for the final evaporation of the brine from sea-water, previously concentrated by the sun and wind.

Miike Coal-field.—This coal-field is situated about forty miles northeast of Nagasaki, in the ken of Fukuoka and Kumamoto, and on the coast of the Gulf of Shimabara. The coal-rocks are exposed in a belt parallel to the coast, with a width of one or two miles, covering an area of nearly twenty-five square miles. They have a general dip of about five feet in a hundred, toward the sea; but in some places they are said to be locally folded and faulted. Near the coast they are overlaid by more recent clay rocks, but taking into account the gentle dip of the coal-strata, it seems probable that they will be found beneath these clay rocks at a depth of not more than one thousand feet, over an additional area of twenty or thirty square miles, making the total available area of this field perhaps fifty square miles.

So far but two seams of coal have been worked; the upper bed, six to eight feet thick, and the lower, separated from this by twenty feet of rock, four to five feet in thickness. A third bed is reported to occur below these, but it has not yet been mined.

This coal-field is actively worked by the Government Mining Office, under Japanese superintendence, and produces annually sixty to seventy thousand tons of coal. The coal is a fat, caking, blacksmith's coal, resembling that of Takashima. It is used principally for salt-boiling, though a small proportion of the product is brought

to Nagasaki and other ports, where it is gradually finding favor as a steam coal. It is also used, to a limited extent, for the manufacture of coke; the different foundries of Nagasaki, Kobe, and Yokohama creating a small demand for this fuel. It has also been used as a gas coal in Yokohama and Tokio, though to what extent I am unable to say.

The Miike coal is somewhat inferior in quality to that of Takashima, containing a larger percentage of ash. From my own assay, of a small hand specimen, this would seem to reach seventeen per cent., but it may be that my sample was unusually bad. The water, by the same assay, was only one-half of one per cent. The coal of the upper bed is said to be the best.

The Miike coal-field labors under a serious disadvantage in that only vessels of very light draught can approach the shore, the water being very shallow, and mud-flats of a mile or more in width appearing at low tide. The coal must, therefore, be taken in these small vessels, eighty or ninety miles by water, to Nagasaki for transshipment, this being the nearest port.

Amakusa Anthracite Fields.—On the west coast of the island of Amakusa are two small coal-fields, each but a few square miles in area. The coal is an anthracite; sometimes resembling a very dense coke, more often solid and lustrous, and sometimes even graphitic. The beds are but two to three feet thick, and two seams only are recognized, though there are probably more. The coal frequently contains a large percentage of sulphur, and is apt to fall to powder on exposure to the weather.

The coal is mined in many places, but only on a small scale. The whole product is used in the neighboring provinces for lime-burning.

Graphite.—In Kagoshima ken near the southern extremity of the island of Kiushiu, a small deposit of graphite has recently been discovered. The graphite occurs in irregular masses, scattered through the fissured, broken, and partially metamorphosed rocks forming the foot wall of a volcanic dyke. Similar well-defined dykes, one hundred to one hundred and twenty feet in thickness, everywhere penetrate the shales and sandstones of this vicinity.

Deposits of coal, of a very inferior quality, are said to occur within a few miles of this place; and, from their reported direction, are probably in the same series of sandstones and shales. It seems, therefore, not unlikely that this graphite may prove to be the result of a local alteration of one of these beds of coal, and that further development of the mine may lead to the discovery of this bed.

The graphite is of good quality, as will appear from the following analyses made by Mr. Gowland, of the Imperial Mint:

	I.	II.
Carbon,	88 09	89.22
Ash (pale-gray),	11 01	10.78
	99.10	100.00

This graphite has not yet been utilized, though experimental crucibles have been made from it which are said to work well.

PRODUCTION OF COAL IN 1874.*

District.	Tons of 2240 lbs.
Takashima Island, Nagasaki Harbor,	72,430
Miike Mines, Miike Coal-field,	66 324
Imabuku District, Karatsu Coal-field,	32,567
Taku " " "	22,198
Karatsu " " "	58,288
Hirado " " "	63,160
Rest of Japan estimated at	74,933
Total,	390,000

Analyses.—I add some assays and ultimate analyses of Japanese coals, made by me some years ago for the Government of Yesso.† The specimens from Yesso either were carefully sampled from large quantities of coal, or were selected to represent the average quality of the different beds. The others were merely hand specimens, and the results are, therefore, less reliable.

* Official estimates furnished by J. G H Godfrey, Chief of Mining Office.
† See American Chemist, vol. i , p. 120.

JAPANESE COALS.

Kayanoma Coal-field, Yesso.

	Name of coal.	1. Moisture at 140° C.	2 Volatile combustible	3. Fixed carbon	4 Ash	5. Ratio of fixed carb to vol comb.	6. Color of ash.	7. Per cent of coke	8 Ash to 100 of coke	9 External appearance of coke.	10 Specific gravity of coal	11 Weight of 1 cub ft. solid.	12 Cub ft required to stow 1 ton, 2240 lbs broken
1	Midzunuki coal, average samples... 4 0 ft.,	3 73	33 03	41 76	21 48	1 264 · 1	Dark reddish-brown	73 78	31 95	Good	1.446	90.38	38 to 46
2	Honshiki coal, upper bench ... .6 4 "	5 71	39 94	50 63	3 72	1.268 1	Light-brown.	54 35	6 84	Very good	1 266	79 09	44 " 52
3	" " lower bench... ..1 3 "	5 51	33 39	46 03	14 07	1 379 . 1	Light-lavender.	60 10	23 41	Fair	1 340	83 76	41 " 50
4	" " average sample from mine,	5 36	35 35	46 11	13 08	1.283 · 1	Light-brown.	59 19	22 10	Very good.	1.351	84 44	41 " 49
5	" " " from "dump,"	4 12	34.88	45 26	15 74	1 298 : 1	" "	61 00	25 80	" "	1 363	85 19	41 " 49
6	Tateiro No. 2, upper bench .... .1 9 ft.,	5 63	32 22	49 38	12 77	1 533 1	Reddish-brown	None.	....	....	1 355	84 69	41 " 49
7	" " middle bench......... 1 1 "	3 43	25 63	36 06	34 86	1 407 . 1	White.	"	.... ..	....	1 539	96 19	35 " 43
8	" " lower bench . ...0.7 "	5 06	33 68	48 71	11 95	1 417 . 1	"	60 66	19.70	Fair	1 346	84 13	41 " 49
9	" " average sample from mine,	5 06	29.93	41 50	23 51	1 386 : 1	Brownish-white.	65 01	36 16	Very poor.	1 411	88 20	39 " 47
10	Kosawa No. 4, upper bench . ...1 6 ft.,	12 98	41 84	38 05	7.13	.0 909 1	Pink.	None.	....	. . .	1 359	84 94	41 " 49
11	" " middle bench . . .... 1 7 "	12 71	44 97	36 55	5 77	0 813 . 1	"	"	.... ..	....	1 367	85 44	40 " 48
12	" " lower bench... .. . .1 0 "	6.19	31 75	44 42	17 64	1 084 1	Reddish-brown.	"	... ...	... ..	1 408	88 00	39 " 47
13	" " calculated average of bed. .	11.51	41 07	38.73	8 69	0 906 1	Light-brown?	"	. .. .	....	1 372	83 55	41 " 50
14	Osawa No. 6, upper benches ....3 9 ft.,	5.43	41 43	43 36	9 78	1.047 · 1	Reddish-brown.	53 14	18 40	Good.	1 286	80 04	43 " 52
15	" " lowest (?) benches. ....1 5 ft.,	4 85	25 30	29 79	40.06	1.177 . 1	White.	None		... .	1 589	99 30	35 " 41
16	Osawa No. 9, 6th branch. ... .1 4 "	6 75	39 03	42 57	11.65	1 091 1	Light-brown.	54.22	21 47	Fair.	1 347	84 19	41 " 49
17	" " 5th " ... . 1 2 "	5 66	41 47	46 44	6 43	1 120 1	" "	52 87	12 16	Good	1 301	81 25	43 " 51
18	" " 4th " ....1 8 "	9 40	38 66	46 47	5 47	1 202 1	Light-ochre.	None.	....	. .. .	1 296	81 00	43 " 51
19	" " 3d " .... 1 4 "	9 55	35 80	49 71	4 94	1 388 1	Pink	"	. ...	. .. ..	1 316	82 25	42 " 50
20	" " calculated average of bed ..	8 03	38 60	46 29	7 08	1 200 1	Light-brown?	?	.. ..	Very poor?	1 315	82.18	42 " 50
21	Ogurasawa No 3, upper bench. ..2.0 ft.,	6.43	35.33	38 44	19 80	1.088 1	White	None	... .	....	1.400	87 52	40 " 47
22	" " middle bench . .... 4.0 "	7 86	35 03	39 28	17 83	1 121 . 1	"	"	. . ..	.. ..	1 410	88 15	39 " 47
23	" " lower bench ....1 4 "	5 91	36 27	33 98	23 84	0 937 1	"	"	..	. . ..	1 423	88 88	39 " 46
24	" " calculated average	7 04	35 37	37.97	19 62	1 074 1	"	"	. ...	. . . .	1 410	88 15	39 " 47
25	Furushiki No. 3	1 34	28 44	54 53	15 69	1 914 . 1	Lavender	70 22	22.20	Excellent	1 326	82 88	42 " 50
26	Chatsunai, Onkosawa No. 1, 5 ft bench .	10 85	39 63	43 46	6 06	1 097 . 1	Reddish-brown.	None	. ...	....	1.334	83 38	42 " 50

Ishikari Coal-field, Yesso.

	Name of coal.	1.	2	3.	4	5.	6.	7.	8	9	10	11	12
27	Horumui No. 1, 4 2 ft. Marked (L 576 i). .	5 62	39 88	52 32	2 18	1 312 : 1	Dark-umber.	54 50	4 00	Very poor.	1 284	80 25	43 to 52
28	" " 2, 5.0 ft. " (L 602 a) ..	5.19	37 51	54 84	2 46	1 281 1	Bright-orange.	57 30	4 03	Poor	1 281	86 06	43 " 52
29	" " 3, 1 9 ft. bench (L 602 ba) .	4.20	40 42	51 99	3 39	1.286 1	Orange-yellow	55 38	6 12	Good.	1 277	79 80	43 " 52
30	" " 3, 5.0 ft. " " . . .	4 25	41 26	52 08	2 41	1 262 . 1	" "	54.49	4 44	Fair.	1 286	83.75	43 " 52
31	" " 3, calculated average	4.24	41 01	52.05	2 70	1 269 1	" "	54 75	4 93	Fair?	1 283	82 37	43 " 52
32	" " 4, 2 0 ft. bench (L 602 ca)	5 03	38 29	53 31	3 37	1 131 . 1	" "	56 68	5 93	Fair.	1 305	81 57	43 " 51
33	" " 4, 2 7 ft " "	4 58	40 67	50 45	4 30	1 240 · 1	" "	54 75	7 85	Good.	1 304	81 52	43 " 51
34	" " 4, calculated average...	4 85	39.24	52 17	3 74	1 174 · 1	" "	55 90	6 67	Fair.	1 305	81 55	43 " 51
35	" " 5, 5 0 ft Marked (L 603 e). ..	4 47	40 80	52 08	2 65	1 276 : 1	Yellow.	54 73	4.84	Good.	1 282	80 14	43 " 52
36	" " 6, 4.0 ft. " (L 603 g)...	8 48	37 52	51 57	2 43	1 108 · 1	"	None.	....	. .. .	1 323	82 69	42 " 50
37	Sorachi No. 1 (Bussankioku collection) ..	2 93	35 03	59 05	2 99	1.686 : 1	Light-yellow.	61 02	4 82	Very good.	1 279	79 74	43 " 52
38	" " 2 or 3 " (Admiral Enomoto)	2 89	35 77	59.02	2 32	1.650 : 1	Orange-yellow.	61.34	3 78	" "	1.272	79 48	43 " 52

Coal from other parts of Japan.

	NIPPON.												
9	Lignite, Kadzuno Mines, Akita ken	14 35	27 14	56 08	2.43	2 066 : 1	Lavender.	None	. ..	....	1 338	83 62	41 to 50
0	Hiyamidzu coal, Iwaki coal-field....	9 84	38 47	41 52	10 17	1 079 · 1	Brownish-white.	"	....	.. ..	1.380	86 22	40 " 48
1	Funakimura coal, Yamagouchi ken..........	11.49	33 13	51 44	3 94	1.552 : 1	Pink.	"	....	....	1.337	83.56	41 " 50
	KIUSIU.												
12	Karatsu coal, Karatsu coal-field	2 69	40 13	47 12	10 01	1 174 1	Yellow. .	57 13	17.50	Very good	1 349	84 31	41 " 49
13	Takashima coal, Nagasaki ken.	1 32	38 13	55 45	5.10	1.454 : 1	Pink	60 55	8 42	Excellent.	1 260	78 78	44 " 53
14	Gas coal, Miike coal-field	0 54	38 51	43 36	17.59	1.126 : 1	Red-brown.	60 96	28 86	"	1 335	83 44	41 " 50

Ultimate Analyses and Calorific Powers.

	1. Midzunuki coal (mine)	4. Honshiki coal (mine)	5. Honshiki . coal (dump).	9. Tateiri coal (mine)	25. Furushiki coal. No. 3.	28 Horumui coal. No 2.	36. Horumui coal. No. 6.	37. Sorachi coal. No. 1.	39. Kadzuno lignite.	42 Karatsu coal.	43 Takashima coal	44 Miike gas coal	Average of 12 Japanese coals.	Average of 8 American* lignites.
Moisture.......	3.714	5 360	4 095	5 060	1 342	5 194	8 479	2 928	14 346	2 690	1 320	0 536	4 589	10 004
Carbon	57.689	62 221	64 412	56 283	69 049	72.982	68 842	77 040	62 149	69 436	78 633	69 280	67 585	63 531
Hydrogen..	4 620	5 222	5.911	4.124	5 256	5 300	4.771	5 685	3 358	5 156	5 816	5 524	4 979	4 092
Oxygen and nitrogen	10.144	10 118	9 940	10 270	7 172	13 841	15 180	11 014	16 395	11 920	8 721	4 888	10 800	16 299†
Sulphur	3.765	1 607	1 449	1 178	2 386	0 353	0.472	0 542	2 116	1 177	0 659	3 488	1 599	1 342
Mineral matter‡.........	20 068	12 472	15 193	23 084	14 795	2 330	2 256	2 791	1 636	9 621	4 851	16 284	10 448	4 732
Total.......................	100 000	100.000	100 000	100 000	100 000	100 000	100 000	100 000	100.000	100 000	100 000	100.000	100.000	100.000
Combined water..	10.062	10 033	9 8 2	10 205	6 718	14 221	15 727	11.041	17 094	12.060	8.461	4 149	10 800	16 955
Free hydrogen.......................	3.502	4.107	3.818	2.990	4 510	3 720	3 024	4 458	1 459	3 816	4 876	5 063	3 779	2 208
Calorific Power I§	5868	6654	6521	5577	7133	7179	6604	7782	5525	6927	8035	7342	6764	5895
Calorific Power II‖	5625	6373	6262	5351	6872	6895	6329	7492	5286	6664	7747	7072	6499	5644
Weight of water (at 100° C.) evap'd by 1 of coal } I¶	10.48	11 88	11.67	9.97	12 81	12 85	11.80	13.96	9.85	12.42	14 44	13.16	12 11	10 52
Weight of water (at 100° C.) evap'd by 1 of coal } II**	6.78	7 66	7.57	6 63	8 16	8 66	8 11	9 11	7 35	8.21	9 32	8.16	7 98	7.47
Temperature of combustion.	2504° C.	2476° C.	2556° C.	2510° C.	2605° C.	2578° C.	2531° C.	2627° C	2374° C	2581° C	2644° C.	2615° C.	2566° C.	2473° C.

* Analyses made by the writer. See *Engineering and Mining Journal*, vol. xv, p. 322 † Including nitrogen, 1 228.
‡ Mineral matter equals ash minus oxygen absorbed by iron of pyrites, or ash minus three-eighths of the sulphur.
§ Obtained by multiplying carbon and free hydrogen by their respective calorific powers—8080 and 34,462
‖ Obtained from Calorific Power I by deducting units of heat required to vaporize moisture, combined water, and water of combustion. (536 5 units for each unit of water)
¶ Theoretical—obtained from Calorific Power II. ** Probable result to be obtained in practice.

PETROLEUM.

Petroleum-bearing springs and natural gas-wells have long been known to the Japanese, but only of late years have they been utilized. According to Japanese writers, petroleum—"burning water" was first found in Echigo, A.D. 615, at Kusodzu, or "stinking water" village, by the name of which village rock-oil is now generally known.

At first the petroleum was probably collected by simply skimming the surface of the water at these natural springs. Later, the springs were cleaned out and enlarged, and pits dug in the gravel and soft clay rock. At one place, Kurokawa, tunnels were made in the hill-side to tap the sources of the oil supply.

The usual practice is to dig wells three feet or more square, and as deep as required. The work of sinking these wells requires five men, working during the day while the light is good. Of these, two are probably skilled workmen, the others laborers who hoist the excavated material. The miners work in short shifts, one remaining at the bottom of the well from nine o'clock to noon only, and the other from noon to three o'clock. The rock in which the wells are excavated would seem to be soft and easily worked, probably with pick and hoe alone, as the oil-bearing rocks belong to the Toshibets group, which group is made up of soft sandstones and shales, and still softer clay rocks. The miner who is not at work remains at the mouth of the well to direct the coolies who are hoisting rock, and, at the same time, to supply his fellow at the bottom with fresh air. The blowing machine by which this is effected is a wooden box sunk in the ground, about six feet long by three feet wide and two feet deep, with a tilting cover, balanced in the middle of its length, and moving between the sides of the box on a horizontal axis. A vertical partition below the axis, containing a small valve, divides the two ends of the box. The workman stands upon the board and walks from one end to the other, thus alternately depressing each, and forcing the air first from one end of the box, and then from the other, into a wooden air-pipe, about eight-tenths of a foot square, placed in one corner of the well. Similar blowing-machines are used in some of the smelting works to supply blast to the furnaces; in this case, of large size, and worked by six or eight men. The earth or rock excavated is raised in rope nets by three men, by means of a rope passing over a wheel one foot in diameter, hung just under the roof of the hut which covers the well. On account of the gas

and inflammable vapor, artificial light cannot be used in mining, and a window of translucent oiled paper is made in the roof over the mouth of the well. At the bottom of a deep well it is said to be as dark as starlight. In certain cases, horizontal galleries are driven from the bottom of the well to increase the yield of oil by draining a large area of rock. In these side galleries the want of light becomes serious, for they are quite dark a few feet only from the bottom of the well. Mr. Lyman suggests as a means of giving light a rude heliostat, made of a number of small mirrors in a window-frame, with a fixed mirror at the bottom to reflect the light into the side galleries, or, for night-work, the use of Geissler tubes.*

The well is timbered with large pieces of board at the corners, and light cross-pieces, which last serve also as a ladder for going up and down, though at such times a rope is tied under the arms of the workmen and held by several men at the top.

The expense of digging a well of this character is not great, the rock usually being soft and easily excavated. One well 900 feet deep is said to have cost but $1000. Shallow pits fifty to sixty feet deep would cost much less in proportion, probably not more than $10 or $12.

The yield of oil is usually small, not often more than a few gallons per day. When first dug, the wells are more productive, yielding sometimes as much as fifteen or twenty barrels. In such cases, however, wells are quickly sunk by other parties as near as possible, often within a few yards, and the yield of the original well falls off rapidly. Whether, in case the underground workings should connect, it becomes usual to resort to spears and matchlocks, or to revolvers and breechloading rifles, as in some other countries, is not stated.

One well, mentioned by Mr. Lyman, dug in 1871, yielded for fourteen days an average of nineteen barrels per day; after that, eight barrels. In January, 1873, the yield was but one-half barrel daily. In February the well, being deepened, gave nearly three barrels a day. From this time the flow diminished till, in December, 1874, the daily yield was about thirteen gallons, when water put a stop to further operations.

The oil is in all cases raised to the surface in buckets, and in wells of small yield has to be carefully skimmed from the surface of the water.

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* Geological Survey of the Oil Lands of Japan. Report of Progress for the First Year. Benjamin S. Lyman, Chief Geologist, etc., Tokio, 1877.

The introduction of kerosene and kerosene lamps from America stimulated the search for oil in new localities and the digging of new wells. The production, though by these means largely increased, probably never reached more than one-sixth or one-seventh of the imports, and has so far only supplied the local demand of Niigata ken and vicinity.

A petroleum bubble of some size was also blown in the shape of a Japanese rock-oil company, which secured a large amount of oil land, bought expensive well-boring machinery, and engaged the services of a foreign adventurer as manager. After spending a good deal of money in expensive borings, which cost more and yielded less than the wells dug by the Japanese method, the bubble burst, and the machinery and oil lands were taken by the government to pay the salary of the manager, etc.

Geologically, petroleum seems to be confined to the clay rocks of the Toshibetsu group. In Yesso, where certain oil regions were examined in the course of the Geological Survey, this is certainly the case;* and the few deposits I have met with on the main island are also in the same group of rocks. According to Mr. Lyman's reports,† the oil regions of Yesso are quite insignificant and hardly worth working; which, indeed, seems to be the case in most of the oil regions of the country.

According to a recent report by Mr. Lyman, in Nagano and Echigo petroleum is found in a series of soft sandstones, clay rocks, and shales, resembling to a certain extent the rocks of the Toshibets group of the Yesso Survey, and nearly, if not exactly, of the same age. These are the most recent of the Japanese sedimentary rocks, alluvium excepted, and probably miocene, tertiary, or even more recent. Formed mostly of volcanic débris, containing in many places layers of pumice, etc., and broken through by dykes and interstratified and overlaid by beds of volcanic rock, the conditions of deposition, etc., were not favorable to the development of animal life, and fossil remains are not abundant. Evidences of vegetable life in the shape of beds of lignite, etc., are more common. According to Mr. Lyman, in Echigo the oil-bearing strata are in part apparently older than those of Yesso, and perhaps cover the gap there observed between the Toshibets group and the Norumui coal group.

Petroleum is found here and there in small quantities in the rocks

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* Kaitakushi Reports, p. 595.

† Kaitakushi Reports, pp. 591 to 631.

of this group over a very large area. The deposits of oil, however, are apparently always local and of small extent, even in the oil regions, and in most cases the quantity of oil is not sufficient to warrant working except on a small scale, and by the simple and inexpensive methods already described.

Oil-bearing strata are found in Southern Yesso at three places: on the northwest coast of Nippon in Awomori, Akita, Yamagata, and Niigata ken; and in the same belt, in Nagano ken in the middle of the island, and in Shidzuoka ken on the southeast coast.

In Yesso, oil occurs at three places: at Yamakushinai, in the province of Iburi, and at Washinoki and Idzumisawa, in the province of Oshima.

At Idzumisawa, near the seashore, twelve and a half miles west of Hakodate, several shallow pits were dug through the alluvium, from the sides of which, in some places, a little oil was seen to ooze, probably derived from the clay rocks below. The oil-bearing bed here seems to be but ten feet thick; and the maximum daily yield of one of these wells was but about half a gallon of very thick, tarry oil, marking 11° Baumé. No deep wells have yet been sunk.

At Washinoki, also in Oshima province, but on the shore of Volcano Bay, similar shallow pits were dug in the gravel, some of which reached the clay rock; these wells yielded in some cases but a trace of oil, and in others half a gallon to one gallon per day. This oil was also thick, marking 15° Baumé. A pit, sixty or seventy feet deep (?), has been sunk through the soft clay rock in this vicinity, since the time of the survey, from which a daily yield of fifty gallons of oil was obtained. The oil is also said to be much lighter than that found near the surface. The report, however, lacks confirmation, and it is possible that the yield has been somewhat exaggerated. Mr. Lyman reports two oil-bearing beds, about two hundred feet apart, each ten feet or less in thickness.

At Yamakushinai, in Iburi province, also on the shore of Volcano Bay, and about twelve miles north of Washinoki, there is, according to Mr. Lyman, a bed of oil-bearing rock probably ninety feet thick, containing, however, but little oil. In one shallow pit a daily yield of about half a gallon of oil, marking 11° Baumé, was obtained, and at several other places mere traces of oil.

These results would seem to show that these clay rocks of Yesso, though extending over a large portion of the island, only locally contain oil, and even then not in sufficient quantity to warrant

working, except on a very small scale, by simple and inexpensive methods of exploration.

The same series of rocks which, in Yesso, contain the oil-bearing strata, are found on the west coast of Nippon, in the ken of Awomori and Akita, and seem to extend along this coast southward through Yamagata and Niigata ken, and then, in a belt across the island, southward through Nagano to Shidzuoka ken on the southeast coast. Oil, in greater or less quantity, is found throughout this belt; but, as in Yesso, only locally, and usually not in workable amounts.

Mr. Lyman was engaged in February, 1876, by the Interior Department of the Japanese Imperial Government, to examine and report upon the oil lands of the provinces of Shinano and Echigo (Nagano and Niigata ken), by far the most important oil region in Japan, producing more than nine-tenths of the total yield. A report of progress* for 1876, just received, gives much new and valuable information regarding the occurrence of petroleum in this part of Japan.

The more important oil regions are those of Niigata ken (old province of Echigo). From Mr. Lyman's report I compile the following table, giving the characteristics of the different oil regions of this ken, beginning with the northwest:

Oil Region.	Area in square miles.	Number of productive wells.	Total yield in barrels daily.	Average yield in gallons from one well daily.	Deepest productive well. Feet.	Largest yield in barrels from one well daily.
Kurokawa Oil Lands, . .	†0 05	28	4.0	1.4	120	0 4
Kauadzu Region, ...	25	106	1 7	0 7	120	0.6
Miyokoji-Kusodzu Region, .	40	178	4.6	1 0	732	0.5
Matsuyama-Tateno Region, .	180	188	15 7	3.0	690	1.2
Other Oil Regions in Echigo, .	. .	22	. .	. .	. .	. .
Totals, ...	. .	522	26			

In the same province are five or six other localities of less importance, some of large extent, within which are numerous exposures of oil-bearing rocks, with traces or small quantities of oil and more or less abundant outflows of gas. In many places this gas is utilized in the houses for cooking and lighting, and arrangements are usually

* Geological Survey of the Oil Lands of Japan. Report of Progress for the First Year. Benjamin Smith Lyman, Chief Geologist, etc. Tokio, 1877.

† "A few hundreds of yards long and still less in width."

made in the village to exhibit for the amusement of the traveller the wonderful burning gas to the best advantage. At one place the gas is used to heat the cold water of a neighboring mineral spring for baths; at another to heat a rude still used for refining the petroleum. The gas is burned from bamboo nozzles, making a large, smoky, and unsteady flame.

The oil of the two northern regions of Echigo comes from the soft sand and clay rocks, and the wells are as a rule shallow; while in the two southernmost regions the oil is found in the somewhat harder shales underlying the clay rocks, and the wells are in many cases quite deep. The oil of the north places is thick, heavy, and colored, while that of the southern localities is lighter and yields more illuminating oil. This difference may be due to a slow evaporation of the oil in the softer and more porous rocks of the northern fields, and at the same time to the shallower depths reached by the wells. Mr. Lyman conjectures that the softer rocks may have thickened towards the north, replacing to a certain extent the shales, which may have thinned out in that direction, and thus that the oil-bearing strata may be identical or of nearly or quite the same age in each case.

The oil wells are sunk wherever the oil appears in springs at the surface, usually where the oil-bearing bed or beds have been brought near the surface by the erosion of the overlying strata, generally on a saddle or one or another side of a basin. The dips are often quite steep, so that the oil-beds quickly sink too deep to be reached by wells, making the productive belt narrow.

In Nagano ken (formerly Shinano Province), which also came within the limit of Mr. Lyman's surveys, there were but three places which yielded as much as eight gallons per day. The rest of the numerous oil-wells reported proved to be quite insignificant, often mere traces of oil or only gas; sometimes a mere smell of gas, hardly to be located, or vague reports of a former outflow of gas. In this connection a statement in the Japanese Official Catalogue becomes interesting: "It is said that after the earthquake, twenty-nine years ago, the oil springs were considerably modified, both the yield and the locality of the springs being affected." *

AMBER.

A fossil resin, resembling amber, occurs in small rounded masses in the coal and lignite of many localities in Japan. Near Kuji, in

* International Exhibition, 1876. Official Catalogue, Japanese Section, page 44.

Kunohe kôri of Iwade ken, such a fossil resin is found, not only in beds of lignite, but also in nodules distributed through a soft greenish sandstone. This sandstone contains beds of conglomerate, and here and there thin laminæ of coal. The strata are nearly horizontal, dipping east about four degrees, and contain amber over an area of about two or three square miles.

The amber deposit is reached by vertical pits about fifty feet deep, at the bottom of which irregular workings follow the sandstone, which is mined and brought to the surface, where the resin is picked out or separated by washing. The pits are very badly ventilated, and neither lamps nor bamboo torches can be made to burn. Strange to say, the miners work for hours in this atmosphere, and are troubled only by a slight headache. One miner obtains from twelve to fourteen pounds of amber per day; and the preliminary work of sinking the pit, requiring one hundred and fifty days' labor, costs but ten or twelve dollars.

The amber is of inferior quality, usually opaque or cloudy, and very much fissured. I could not learn to what use it is applied; but it is sent to Tokio, and is probably used for making ornaments. At the time of my visit, the miners had about a ton in stock awaiting order from Tokio. The field is nearly exhausted; but similar deposits are reported to occur in several other parts of Japan.

IRON.

Of the metallic minerals, the ores of iron are the most abundant. Nearly all the different ores are found in Japan, but magnetite and magnetic iron sand are the most important, being used almost to the exclusion of all others. Probably one-third, and perhaps one-half of the iron made in Japan is produced from iron sand by a very interesting direct process, which I shall have occasion to describe at another time.

Iron Sand.—From an imperfect list of localities, compiled from various sources, I find that iron sand occurs in twenty-five of the thirty-five ken of the empire. According to the official list of mining permits, there were over four hundred different mines of iron sand worked in 1874. The volcanic and many of the metamorphic rocks contain magnetic iron in fine crystals; and, in the disintegration of these rocks by the action of the sea, the heavier iron sand is separated and forms beds of greater or less thickness on the shore. The old alluvium, formed in a similar way, but now elevated above the sea

in high terraces, contains similar beds, often buried below thick layers of sand and clay. Finally, in many places, the volcanic or metamorphic rock contains so large a proportion of magnetic iron that it is found profitable to mine it and separate the iron sand by crushing and washing.

As an example of the first class, we may take the beach deposits of iron sand in Yesso. The following notes are condensed from Mr. Lyman's description in his preliminary report.*

Magnetic iron sand is found on the sea-beach near Yamakushinai, in Iburi province, on the shore of Volcano Bay; and near Kobui, in Oshima province, on the eastern extremity of the peninsula east of Hakodate. Iron sand occurs in many other localities; but these are the only workable places yet found.

The deposit at Yamakushinai is perhaps ten miles long, and averages twenty yards in width, with a mean thickness of about six inches, making a total of about 120,000 tons of pure ore. The ore, previously washed, was used some twelve years ago, in a forge in the vicinity, for the production of iron by the Japanese process; but it was found difficult to smelt on account of the presence of titanic sand.

The iron sand of Kobui is said to be more easily smelted and seems to be purer. The deposit is, however, very small, amounting, according to Mr. Lyman, to not more than 5000 tons.

As an example of the occurrence of iron sand in the old alluvium, I will describe briefly the important deposits of Kunohe kôri of Iwade ken, which I visited in the fall of 1874. The ore deposits occur on an extensive sloping terrace or table-land, composed of metamorphic rock, mica schists, quartzites, etc., one hundred and fifty to three hundred feet about the sea, and everywhere covered by beds of yellow sand and sandy clays forty to fifty feet thick. The ore is a dark red sandstone, with thirty to fifty per cent. of iron sand in thin laminæ, or distributed through the mass. It occurs locally on the surface of the metamorphic rock and under the alluvium, in beds one to three feet thick. This sandstone, which is quite friable, is easily crushed, and the magnetic sand separated by washing.

The surface of the table-land is much cut up and eroded by small streams, and crossed in several places by deep valleys of larger rivers. The deposits of iron ore are in this way frequently uncovered, and

* Kushi Reports.

secondary deposits are formed in the beds of the smaller streams. In many cases, however, the action of the streams merely removes so much of the overlying sand and clay that the ore is found within twelve or fifteen feet of the surface.

Over the whole extent of this table-land, for a distance of fifteen to twenty miles north and south, and seven miles east and west, the ground has been explored by shallow pits. The productive beds being local and of limited extent, but a small proportion of these explorations have been successful. When, however, the miner is so fortunate as to strike such a bed of iron sand, he burrows horizontal drifts in all directions and follows the bed until it becomes too thin to work; extracting the ore without system save to get as much as possible without endangering his own safety.

M. Sévoz, in the *Annales des Mines*,* gives an analysis of a Japanese iron ore which is interesting in this connection. The ore forms about two per cent of a partly decomposed granite, from which it is extracted by washing. From the analysis this washed material is an impure magnetic sand containing the proper proportion of ferrous and ferric oxides, six per cent. of titanic acid, twelve per cent. of silica, etc.

Magnetite.—An imperfect list of the places in which magnetite is found, compiled from various sources, develops the interesting fact that these localities lie in a belt extending from Iwade ken south and southwest to Sakai ken, a distance of more than three hundred and fifty miles. The northernmost place is in Hei gôri in Iwade ken. Here there are mines, seven to thirteen miles from the coast, which supply certain recently erected government blast furnaces. South of this several localities are reported in Miyagi ken. Still southward, the next deposits, one of which was examined lately by an American engineer, are in Fukushima ken, where the ore is but five miles from the sea. Southwest, magnetite again occurs in Tochigi ken, and in several places in Gumma ken. At Nakakosaka in Gumma ken, not far from Tokio, an English engineer has recently erected a blast furnace. Still southwest, magnetite is reported to occur in the ken of Nagano, Gifu, and Sakai. Of these localities we know little or nothing, except that the ore of this southern end of the belt is reported to be of medium and inferior quality, as compared with that of the northern mines.

In addition to the above localities, magnetite of excellent quality

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* A. d. M., vol. vi, 1874; quoted by American Chemist, vol. vi, p. 38.

is said to occur in Okayama ken, in the southwestern part of the main island.

From Mr. Plunkett's report, and additional details furnished by Mr. Godfrey, I condense the following description of the deposits of Hei gôri in Iwade ken, where the Mining Office is building blast furnaces and preparing to produce iron on a large scale.

The principal iron mines are about thirteen miles from the coast, though deposits of ore have recently been found at half that distance. The magnetite occurs in vertical beds, twelve or fifteen feet thick, in a dark blue feldspathic diorite (quartzite or felsite?). The ores are rich and very pure, quite free from sulphur, and contain little or no titanium.

It is proposed to connect the mines by a tramway eleven miles long with the furnaces, and these with the harbor of Kameishi, two miles beyond, by a continuation of the same. The iron will be shipped to Yokohama or Nagasaki, and coal brought back as return freight. At present charcoal is used as fuel. Mr. Godfrey estimates the cost of producing iron here at nine dollars per ton; but this apparently does not include repairs, or interest on capital or sinking fund, while all the items, especially that of fuel, are placed very low.

At present the product is but 1500 tons per year; this, however, will soon be largely increased. According to the catalogue of the Japanese section, four blast furnaces, calculated for a daily yield of 15–20 tons, and twelve puddling furnaces, with coke ovens, etc., will shortly be erected here. The full plant of a large rolling-mill, including rolls, steam-hammers, etc., has been ordered from England, and is, according to M. Deby, even now on the way to Japan.

In Fukushima ken, Naraha kôri, magnetite occurs in beds twelve, fifteen, and even twenty feet thick. The ore is rich and generally quite pure, but sometimes contains sulphur in the form of pyrite, in objectionable quantity.

At Nakakosaka, in Kamura kôri, of Gumma ken, where Messrs. E. H. M. Gower and J. A. R. Waters, English engineers, have erected a blast furnace for a Japanese company, the magnetite occurs in beds eight to eighteen feet thick, dipping about twenty degrees, and interstratified with a dark-blue quartzite (or felsite?). The ore is apparently of good quality, but has not yet been analyzed. An almost inexhaustible supply can be obtained at small expense by quarrying. According to Mr. Gower, iron can be made here for nineteen dollars or less per ton. The fuel, charcoal, costs about two

and a half times as much as at Hei gôri. The mines and furnaces are quite near a navigable river, by which the product can be brought directly to Tokio or to Yokohama.

Other Ores of Iron.—According to Mr. Geerts,* specular iron ore is found only in Kagoshima ken; impure red hematite is more common, occurring in many places; limonite, massive and concretionary, and clay iron ore or kidney iron ore are also common and abundant. He gives a list of places, compiled from Japanese authorities, in which the ores are found; but says nothing of the extent or character of the deposits. I have received many specimens of the above ores, and of bog iron ore; the latter not mentioned by Geerts, but perhaps included under limonite. These ores are used to only a small extent for the production of iron.

COPPER.

Although copper has been mined and smelted in Japan for nearly twelve centuries, the active working of the copper mines, as we have already seen, dates back less than three hundred years. The average annual production for the first two hundred and fifty years of the three hundred I would estimate at about 2800 tons.† According to Von Siebold,‡ the annual product in 1830 was fifty to sixty thousand piculs, which would equal 3333 to 4000 tons; while, according to the estimate of Mr. Godfrey, the present annual yield is about 3360 tons. This yield, as Mr. Plunkett remarks,§ represents the product of about two hundred different mines; but, as will presently appear, four mines furnish about one-half of this amount.

Copper is found nearly everywhere in Japan. A list of localities, which I have compiled, shows that out of thirty-eight ken and fu, copper is reported to occur in thirty-three. The records of the Mining Office show that permission has been granted to explore or to work copper deposits in more than four hundred different places.

Many if not most of these so-called copper mines are very poor, and few can be worked with profit, even in those parts of Japan where labor commands but a few cents a day; but the abundance and wide distribution of copper deposits is interesting and encouraging.

Thus far the copper mines and copper smelting works have been

* Transac. Asiat. Soc. of Japan, vol. iii, part 1, p. 6, et seq.
† Of 2000 pounds.
‡ Quoted by Geerts, Transac. Asiat. Soc. of Japan, vol. iii, part 1, p. 43.
§ Mines of Japan, p. 12.

conducted according to Japanese methods, no "western improvements" having been introduced either by the government or by private enterprise. The secret of this conservatism lies in the fact that the more important copper mines and smelting works, as conducted, yield large profits, which the owners are afraid to jeopardize by any change; while in the case of their silver and iron mines, which have not been very profitable, they are willing and ready to accept and act upon foreign advice.

Ores.—Copper occurs generally as chalcopyrite, associated with pyrite or pyrrhotite and other sulphides. Occasionally a specimen contains a little erubescite, which mineral also was formerly found as an ore at one mine. Fahlerz (or tetrahedrite) and copper glance are also common ores, the former often containing silver. Native copper is quite rare, though occurring at several places. A specimen was given me by the superintendent of the Osarisawa mine, in Akita ken, as a great curiosity. The oxidized ores are rare, malachite and azurite occurring only in small quantities at certain mines. Cuprite (copper oxide) is more common, but is not often smelted. It serves the miner, however, as an important indication of copper; and, as such, often determines the course of his drifts and stopes.* Copper sulphate occurs in many mine waters; but is, I believe, not used for the extraction of copper. This water is, however, sometimes evaporated for the production of the salt.

Silver minerals are often associated with the ores of copper in the same vein. Of the permits granted by the Mining Office for the working of copper mines, nearly forty per cent. were for this class of deposits.

The copper ores of Japan are usually poor; containing, as mined, from two and a half to seven per cent. By washing, these ores are concentrated to yield eight to sixteen per cent of copper, twelve per cent. being the average richness.

Copper ores occur in Japan only in veins. These sometimes have all the characteristics of true fissures, but are more often of limited extent, and apparently only gash veins. In either case there is usually a certain amount of parallelism between the different veins in the same region, and, according to their direction, they may be grouped into two or more series, often differing somewhat in their characteristics.

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* Burger, quoted by Geerts, Trans. Asiat. Soc. of Japan, vol. iii, part 1, pp. 31 and 33.

The thickness of the veins varies from a few inches to three or four feet. The average thickness is less than one foot. The deposits are almost always of limited extent, and much dead work has to be done for exploration.

Metallurgy of Copper.—In the introduction I have briefly described the method of working employed in the mines of copper, and here a few words concerning the smelting process will not be out of place. This process, in its most perfect form, may be summarized as follows:

1. Roasting of ore in kilns.
2. Fusion of roasted ore in low hearth, producing matte and black copper.
3. Roasting of matte in kilns.
4. Fusion of roasted matte, producing impure copper, taken off in rosettes or cast in ingots, and a second matte, which is roasted and returned to the same operation.
5. Fusion of black copper from the ore fusion, producing impure rosette or ingot copper.
6. Fining and refining; usually divided into two operations, producing pure cake copper.
7. Fusion of slags.

When the ore contains silver, the black copper and copper from the matte fusion are treated with lead by a very effective liquation process, which I hope to describe at another time. The fining and refining of the copper is effected after the separation of the silver and lead. The fuel used for smelting is invariably charcoal, wood being used in the roastings. The furnaces are simply low hearths, excavated in carefully prepared beds of charcoal, and provided with a partial cover of clay for retaining the heat, and with large hoods for carrying off the noxious vapors and products of combustion. The roasting kilns are usually rude rectangular structures built of stone. The blast for smelting is supplied by very ingenious wooden bellows worked by man-power. The smelting is always conducted on a small scale, and one operation rarely lasts more than a few hours.

As illustrations of the copper mines of the country, I will describe in detail, from my own notes, a few of the larger and more important.

The Ani Copper Mines, in Yamamoto kôri, of Akita ken, are among the largest and most important of the country. These mines extend over thirty or forty square miles, in which area there are many hundred different veins. In 1873 over three hundred of these

were yielding ore, while there were perhaps twice as many not worked.

The most important and best-defined fissures have a general north and south direction, more or less parallel to the strike of the rocks. Those of a second series, which comprise the majority of the veins, have a general east and west direction. The veins of this series are of limited extent. The veins of a third series run northeast and southwest. The north and south veins are said to contain a larger proportion of galena than the others. The country rocks are sandstones and shales, often more or less metamorphosed, associated with volcanic rock in dykes (?) and erupted masses.

The copper veins are usually thin, and the ore-seams vary in thickness from a few inches to three feet, ranging usually between four-tenths of a foot and one foot, the average being five to six-tenths of a foot. The average richness of the ore from these mines is about five and a half per cent.; in certain districts, seven and a half to eight per cent. When concentrated by washing, the ore yields ten to sixteen per cent. of copper, the average richness being about twelve and a half per cent. The ore is copper pyrites, tetrahedrite (?), and other copper sulphides, associated with which are pyrite, galena, blende, etc., and sometimes malachite and azurite in small quantities. The ores also contain silver and sometimes gold.

These mines have been worked for centuries with great skill, yielding large profits. The old Japanese methods of mining and smelting are still retained. At present, nearly three thousand men, women, and children are employed in the mines and smelting works. In 1873 the total product was $514\frac{1484}{2000}$ tons of copper, while in 1872, according to Mr. Plunkett, the yield was only $443\frac{266}{2000}$ tons.

The copper is sent by river to the Kagoyama smelting works, where it is refined, being previously treated with lead, by liquation, for the separation of the silver.

These Ani mines, with about sixty gold, silver, copper, lead, and other mines in different parts of the country, formerly belonged to Ohno, a wealthy Japanese merchant, but since his failure they have reverted to the government, and are now under the control of the Mining Office. I am informed that it is proposed shortly to put these mines under foreign superintendence, with the view of substituting for the Japanese processes better and more economical methods of working. The results of this experiment will be of great interest, as these mines are among the best managed and most profitable in

the country, and represent the best phase of Japanese mining and metallurgy.

The Osarisawa Copper Mines, situated in Kadzuno kôri of Akita ken.—These mines are now actively worked on a large scale by Mr. Okada, a Japanese merchant of Tokio. Japanese methods alone are employed, though an unsuccessful attempt was made some years ago by Japanese to introduce reverberatory furnaces for roasting and smelting. The ore occurs in nearly vertical fissure (?) veins, having a north and south direction, with branch (?) veins running east and west. The veins traverse slates and metamorphic sandstones, with which are associated masses of volcanic rock (trachyte?).

The veins are somewhat larger in the average than those at the Ani mines, but the seams of ore are about the same size, averaging six to eight inches. An ore-seam five feet in thickness, however, is reported to have been at one time worked. The ore was formerly rich, but at present the average is about five per cent. or less. Concentrated by washing, this ore yields eight and a half to nine per cent. In 1873 the average was 13 per cent. of copper. The ore is copper pyrite, with sometimes a little erubescite, and is associated with pyrite and other sulphides.

The production of this mine in 1874 was about 300 tons of copper; in 1873, 346 tons. Formerly, when the ore was richer, the annual yield is said to have been over 600 tons.

The copper is not refined, but is sent to market as crude copper in the form of rectangular pigs, branded with the name of the merchant in Japanese and English characters, and with the inscription in English letters: "Copper Mine in Kazuno of Tictiu" (Rikuchiu).

Copper Mine in Sakai ken.—Mr. Plunkett's report contains a description, by Mr. Gowland, of the Ozaka Mint, of a large copper mine in Yoshino kôri of this ken, from which account I extract the following details:

The ore is copper pyrites, associated with pyrite and pyrrhotite. The ore-seams vary between one and a half and three feet in thickness, are sometimes split into two, and often end abruptly. The gangue is calcspar and quartz. The yield is fifteen to twenty tons of copper per month, so that the annual product must be over two hundred tons. The mine is worked by Japanese methods, and yields large profits.

Kinonebira Copper Mine.—This mine, which I visited while on

the Island of Kiushiu, last summer, is situated in the village of Okawachi, in Ashikita kôri of Kumamoto ken.

The ore occurs in fissure veins, running east and west, and dipping twenty to thirty degrees. The average thickness of these veins is said to be three and a half to four feet, the greatest thickness six feet. The ore-seams vary between seven-tenths and one and a half feet; though reported sometimes to reach a thickness of four feet. The richness of the ore varies between seven and twenty per cent., averaging thirteen per cent. The ore is copper pyrites, without gangue, except included fragments of a dark-blue, slaty wall-rock.

This mine has produced largely, but is now flooded with water, so that but four or five tons of copper are produced per year. A new drainage-tunnel was begun in 1872, which was, at the time of my visit, three years later, nine hundred feet long, and within about fifty or sixty feet of the vein. The face of the tunnel was then in very hard rock, and the progress was but one and a half feet per month.

Kumayama Copper Mine.—Mr. Geerts* speaks of a large mine in Yehime ken, on the island of Shikoku, which is known as Besi san, or Kumayama. The ore is copper pyrites and tetrahedrite, associated with other sulphides, and contains silver. Mr. Geerts calls this the largest copper mine in Japan. If so, the annual production cannot be less than five or six hundred tons. With the first three mines described, viz., Ani, Osarisawa, and the one in Sakai ken, we thus have four mines yielding a total of fifteen hundred tons per year—about half the product of the empire.

I add an estimate, taken from Mr. Plunkett's report, of the cost of producing one ton (2240 lbs.) of copper by Japanese methods:

Cost of ore,		$43 70	= 23 per cent.
Explorations,		5 70	= 3 "
Treatment of ore	Labor,	87 40	= 46 "
	Material,	34 20	= 18 "
Superintendence,		19 00	- 10 "
Total,		$190 00	

This does not include cost of transportation to market.

* Trans. Asiat Soc. of Japan, vol. iii, part 1, pp. 28 and 40.

LEAD.

The deposits of lead ore in Japan are neither numerous nor valuable. Galena is the only ore used, though other ores are probably to be found. I have so far met with no specimens of oxidized ores, nor can I find any mention of such. According to Geerts,* jamesonite and plagionite, antimonial sulphides, are found in many parts of Japan. These are, of course, not used as lead ores.

Galena occurs in Japan only in veins, usually associated with copper or silver ores; and lead is, in most cases, a by-product of mines worked for other metals. In 1874 there were thirty-five mines producing lead, of which eleven were worked solely for that metal; and, in all but two of the remaining cases, lead was only a secondary object of exploitation.

These thirty-five mines produced, in 1874, but 207 tons (of 2000 lbs.) of lead, more than half of which was the product of a single mine. Of the remaining mines, probably two-thirds yielded during the year less than 1 ton of metal each.

The explanation of this small production is to be found in the character of the deposits. The veins are usually thin, and always irregular and pockety. A large amount of exploring work must therefore be done, usually with very unsatisfactory results. A seam of ore four inches thick, when discovered, will pay the cost of working; but the average thickness of the ore deposits barely reaches this limit. Ore-seams one foot thick are very rare; and the discovery of a pocket of ore four feet in thickness will be carefully chronicled and the tradition handed down for centuries.

For these reasons lead mining is usually, in itself, unprofitable. As a rule, the mines are worked only to supply the lead necessary for the extraction of silver from its ores or from argentiferous copper; in which cases the cost of the lead is of secondary importance, and it may even pay to work the lead mine at a positive loss. In this lies also the explanation of the large imports of lead, though deposits of galena are by no means rare.

Lead Smelting.—The process by which lead is extracted from the ore is very simple. The ore is crushed and carefully washed, and all blende, pyrite, gangue, and other impurities removed, leaving nearly pure galena for treatment. The process may be summarized as follows:

* Trans. Asiat Soc. of Japan, vol. iii, part 1, p. 87, et seq.

1. Roasting of washed ore in kilns, producing a little lead, which is added to that of the next operation.

2. Fusion of roasted ore, with the addition of cast iron, in a low hearth, producing lead, which is cast into pigs.

3. Fusion of slags.

With certain ores, a little *yuhada*, or crass, is sometimes produced. This is roasted and returned to the ore fusion. The slags are picked over and washed before treatment.

Conducted by skilled workmen, this rude method produces excellent results. At one place which I visited, sixty per cent. of lead was obtained from an ore containing perhaps seventy or seventy-five per cent. Japanese smelters, however, are rarely so skilful, and the yield is not often so large. Mr. Gowland* speaks of works which he visited, where, from ore yielding sixty-nine per cent. by assay, but forty per cent. was obtained; and at Innai, where metallic lead is used for the extraction of silver, I found, in the simple fusion of this lead with the silver ore, a loss of fifty-seven per cent.

When the lead contains silver, this is separated by a rude cupellation with charcoal on an open wood-ash cupel; and the resulting litharges are reduced again to metallic lead by fusion with charcoal in a low hearth.

Daira Lead Mines.—These mines, situated in Yamamoto kôri, Akita ken, are probably the most important of the country. They lie near the head-waters of the Fujitokawa, a branch of the Noshiro river; and near the junction of these streams are situated the celebrated Kagoyama smelting works, where the lead from these mines is used in the treatment of the argentiferous copper of Ani. These lead mines were, at the time of my visit, worked by the merchant Ohno; and with the Ani mines, the Kagoyama smelting works, etc., have since reverted to the government, and are now under the control of the Mining Office.

The date of the discovery of these lead mines is unknown. More than three hundred and fifty ancient tunnels can now be counted on the neighboring hills, and doubtless the real number is much larger. Within an area of about one and a half square miles, ninety-four different veins are known, twenty-seven of which are now producing ore. These veins can usually be traced for several thousand feet, though the ore bodies do not continue of workable thickness for any great distance. The veins are true fissures, usually one to two feet

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* Mines of Japan, p. 25.

thick, sometimes larger. With few exceptions, they run east and west, dipping at a high angle (50° to 60° S.). The ore is galena, associated with blende, copper and iron pyrites, and other sulphides, and occurs in irregular lenticular masses in the vein rock. These ore bodies are fifty to four hundred feet in their greatest extent, and from two-tenths of a foot to two feet in thickness. The average diameter of these lenticular masses is about one hundred and fifty feet, and the usual thickness three to six-tenths of a foot. If thinner than three-tenths of a foot they cannot be mined with profit, and in such case are followed only for the purpose of exploration.

The vein rock is sometimes quartz, but usually a white porphyry, which is often much decomposed. The veins have often a symmetrically banded structure, with regular seams of ore, pink carbonate of manganese, blende, quartz, etc. Near the surface the carbonate of manganese is changed into the black oxide. Sometimes the veins are simple fissures in the country rock, containing galena mixed with pyrite and blende, and without gangue.

The country rock is a hard, dark-blue argillite, with beds of sandstone, etc. The strata are sharply folded, the general direction of the axes being north and south, or a little to the east of north. The dips are steep, 45° to 70° toward the east and west.

With these stratified rocks are associated large masses of a white porphyry, similar to the rock filling some of the veins. These apparently occur as intruded masses or dykes, with an east and west direction parallel to the strike of the veins, and across that of the sedimentary rocks. Ore-bearing fissures are found in these masses of porphyry, as well as in the stratified rocks.

The richness of the ore is not known, as it is bought from the miner in the form of nearly or quite pure galena, which has been separated from the gangue and the sulphides by washing. This washed ore yields, in the furnace, about 60 per cent. of lead.

The mines employ at present about four hundred persons, including officers and workmen, men, women, and children. The men earn about eight cents per day and the women five.

The product for 1874 was about one hundred and five tons (2000 lbs.) of lead. This is below the average, which, in past years, has been about one hundred and thirty tons.

The lead contains 0.075 to 0.1625 per cent. of silver, which is separated at the Kagoyama Smelting Works.

These mines are admirably managed, and apparently with great economy, but in spite of this the profits are very small, and, indeed,

were it not for the necessity of supplying the Kagoyama Works with lead, it is probable that the mines would be abandoned.

Yurap Lead Mines.—Yamakushi kôri, Iburi Province, Yesso. In the course of my work for the Geological Survey of Yesso, I spent some time at these old mines. It was intended to make a careful survey of the region, but the work was interrupted by cold weather, and was not afterwards resumed.

The lead deposits of Yurap bear a striking resemblance to those of Daira. The country rocks are dark-blue, slaty rocks and quartzites, much folded, and having a general north and south strike. The stratified rocks, like those of Daira, are traversed by small veins and large dykes of a white porphyry, having an east and west direction. The ore-bearing veins are found both in the quartzite and in the porphyry, and are filled with the same minerals as at Daira, galena, blende, copper, pink carbonate of manganese, quartz, etc. These minerals are here, also, sometimes symmetrically arranged in seams within the vein. Veins containing only quartz and ore, and without gangue rock, complete the resemblance between these and the Daira deposits.

These mines have been abandoned for a number of years, and at the time of my visit I could find no one who was familiar with the old workings. The old stopes which I examined had been exhausted, and I saw little or no ore. Others, who visited these mines at an earlier date, report that they saw ore-bodies a few inches to a foot thick.

From the very remarkable similarity between these veins and those of Daira, it is probable that the Yurap mines could be worked, should a necessity here arise for a supply of lead. In view, however, of the fact that labor is much more expensive in Yesso than in Nippon, it is also probable that the profits would be even less than at Daira, though the works should be conducted on the most approved methods.

Other deposits of lead occur in Yesso, but none of importance. At one place the deposits closely resemble those of Daira and Yurap, but the veins are small and not workable.

Towada Lead Mine.—Akita ken. This mine was opened some years ago by the Mining Office, with the view of obtaining a supply of lead for the smelting of the Kosaga silver ore. The explorations had, at the time of my visit, revealed no large bodies of ore. A few fine specimens of galena, since divided among the museums of Tokio, constituted, in fact, the total product of the mine. I have lately

been informed that this mine is now paying expenses. Larger bodies of ore, therefore, have probably been discovered.

—— *Lead Mine.*—Yeichi (?) kôri, Shiga ken. The following notes concerning this mine are condensed from Mr. Gowland's description:*

The vein is large and wide, but is chiefly filled with a blue, shaly material, through which the ore occurs in thin, straggling seams, and in irregular pockets, associated with similar seams of calcspar. The vein has a steep dip; its course, however, and the direction of the dip are not stated. The country rock is a silicious shale, much broken up and decomposed near the surface.

The ore is galena, associated with iron oxide, magnetic and arsenical pyrites (mispickel), and sometimes copper pyrites. The ore is poor, yielding, in the furnace, but 4 to 5 per cent. of lead. Small quantities of purer galena are sometimes found. A sample of ore of this description, from a seam ten inches thick, gave Mr. Gowland, by assay, 69 per cent. of lead and 125 oz. of silver to the ton. This yielded the Japanese smelters but 40 per cent. of lead.

The mine is worked by levels driven into the hillside, and is drained in the usual manner. The workings are very irregular. Gunpowder is used only in hard rock. Mr. Gowland does not state the yield of the mine, but it is probably not large. The lead produced contains 8 per cent. of silver, so that the mine should be regarded as one of silver rather than of lead.

SILVER.

The metallurgy of silver, and its extraction on a large scale, probably date from the year 1590, when the Japanese first learned from a foreigner to separate silver from lead and copper. The discovery of silver and its first production are placed by the Japanese, as we have already seen, some ten centuries earlier. Between 1649 and 1671, the Dutch exported one hundred and forty millions of dollars in silver bullion; and, even supposing a large proportion of this to be silver previously produced from the mines, or brought into the country by the Portuguese for exchange with gold, the yield of the country cannot have been less than three or four millions of silver per year. Comparing this with the present annual yield, 312,000 ounces, or in value about $350,000, it is evident that there has been

* Mines of Japan, p. 25.

a great falling off in the production of this metal. This is due to the causes already stated, viz., the abandonment of many mines on account of the rise in the value of labor, and the practical exhaustion, so far as Japanese methods of mining are concerned, of the more accessible and easily worked deposits. The silver deposits of Japan constitute, however, the most valuable portion of its metallic wealth, and offer the greatest inducements for the investment of capital. When the abandoned and the feebly worked mines of silver shall be reopened and properly worked, the annual production of silver will certainly equal, and may possibly exceed, that of former times. The silver-bearing veins are, as a rule, true fissures continuous in depth; the bodies are regular and persistent; a constant supply of ore can all times be depended upon, and there is still left below water-level, in the abandoned mines, vastly more ore than was ever obtained above.

Silver occurs in twenty-five of the thirty-eight ken and fu, and in 1874, ninety-eight mines were producing larger or smaller quantities of bullion. The total yield, according to Mr. Godfrey, was about 312,000 ounces troy. Of this amount probably one-half was the product of ten mines, and thus the remaining ones must have averaged nearly 1800 ounces of bullion; certainly a very promising exhibit when we consider the imperfect methods of working employed.

Silver occurs associated with ores of copper and of lead, and sometimes with gold. Of the ninety-eight permits for silver mining granted in 1874 by the Mining Office, but thirteen were for silver alone, the remainder for silver with copper or lead, or with both copper and lead. But three were classed as gold and silver mines; a much larger proportion than this, however, produced bullion containing from one to ten per cent. of gold.

Native silver, argentite, and antimonial silver ore are, so far as I know, the only silver minerals found in Japan. Other sulphides probably occur, but they have not as yet been recognized. Silver also occurs in tetrahedrite, galena, copper and iron pyrites, and in blende, in larger or smaller quantities. M. Coignet* describes a peculiar ore or mineral of silver containing organic or bituminous matter, which was found in one of the mines at Ikuno, in Toyóka ken.

Silver occurs in Japan in true fissure veins through stratified

* An. des Mines. Tome vi. 1874. Quoted by American Chemist, vol. vi, p. 40.

rocks, and in irregular mass deposits distributed through volcanic rock. The ore in the first class of deposits is found usually in regular and well-defined seams in the vein, and rarely in pockets or lenticular masses. In the mass deposits the occurrence of ore is more irregular and uncertain.

The Japanese method for the extraction of silver from the ore is always by fusion with lead. When the ore contains a large proportion of copper, there is a previous fusion for copper matte or for black copper, which are afterwards treated with lead. In the first case the matte is alternately roasted and fused with lead till the copper is entirely lost in the slags. In the treatment of black copper with lead, by the admirable liquation process already referred to, the copper is saved and the silver more perfectly separated. Ores free from copper are fused directly with lead, though sometimes previously roasted to agglomerate the fine material. The silver-lead, however obtained, is cupelled with charcoal on an open wood-ash cupel, as already described. The loss of lead is generally very great; and, with few exceptions, the proportion of silver saved is not usually more than sixty per cent. of that contained in the ore.

The following mines, which have come under my notice, are among the most important in Japan, and will serve to illustrate the different classes of silver deposits:

Kosaga Silver Mine, Akita Ken.—This mine is now worked by the Mining Office, and is under the superintendence of Mr. Curt Netto, a German mining engineer. The works, which consist of several shaft-furnaces, reverberatories, an English cupelling-furnace, etc., were built by Oshima, of the Mining Office, from plans said to have been furnished by Mr. Pumpelly while in Japan. The works are well arranged, but the process proves to be unsuited to the ore, which is very poor. For this and other reasons, Mr. Netto has decided to materially change the process, in such a way, however, as to utilize a large proportion of the old plant.

The ore, which is found within a short distance of the works, occurs in irregular masses, distributed through a white feldspathic porphyry. The porphyry occurs as a massive eruption on the flank of a range of hills of stratified rock. The erosion of this porphyry, which is soft and easily decomposed, has formed a wide valley, and the rock is almost everywhere covered and concealed by deposits of alluvium. Its limits have not been determined, but I found exposures in a belt a mile or more in width, and fifteen or twenty miles in length. Ore has so far been found in the porphyry only in

this one locality, but similar deposits may possibly be concealed by the river alluvium.

There are two classes of ore, both poor, but found in unlimited quantities. The first is a yellow-clay ore, consisting of decomposed porphyry stained by oxide of iron. This contains four to forty ounces of silver to the ton; and, exceptionally, as much as one hundred ounces. The second class is a black sulphuret, mostly amorphous blende, containing about twelve ounces of silver to the ton, and five per cent. of copper. Beside these, certain silicious ores, containing traces of silver, are used in the furnace as flux. The ore, as mixed for smelting, contains on an average thirteen and a half ounces of silver.

The porphyry in which these masses of ore are found is often locally charged with pyrite, which assays 0.015 oz. gold, and 0.73 oz. silver to the ton. Mr. Netto thinks that the clay ore is possibly formed from this by decomposition, with concentration of the silver by segregation.

The ore occurs in the porphyry in large irregular masses. One such mass of black ore, which was partly exposed to the open air, measured about thirty-five by twenty-five by fifteen feet.

The process used for the extraction of silver at the time of my visit was as follows:

1. Roasting of ore in piles—the blende and part of the flux being submitted to this treatment.
2. Fusion for matte in shaft furnaces.
3. Roasting of matte in piles.
4. Fusion of roasted matte with lead in a low hearth by the Japanese process.
5. Refining and cupellation of the lead.

Operations 3 and 4 are several times repeated, until the matte is reduced to very small bulk and most of the copper has been brought into the slags. These rich slags go back to the ore fusion in the blast furnace.

It is proposed, in order to obtain a larger proportion of the silver, to save the copper now lost, and to avoid the use of lead, which must now be brought from a distance, and for other reasons, to adopt a wet method of treatment. The matte from the shaft furnace is to be granulated, roasted with salt in a reverberatory furnace, and lixiviated after the Ziervogel method. Experiments to test these proposed changes had just been completed at the time of my visit, and had proved very successful. I have since been informed that these changes have been made, and give very satisfactory results. In

1874, 3497 tons of ore (of 2240 lbs.?) were treated, yielding 172 oz. gold and 22,621 oz. silver.*

Mukoginzan, Ani Mines, in Akita kôri, Akita ken.—On the other side of the river from the Ani copper mines, and under the same management, is the Mukoginzan (literally, the opposite silver mine). The mine, at the time of my visit, belonged to Ohno, and is now under the control of the Mining Office. I understand, however, that it is still worked by Japanese methods.

The ore, like that of the Kosaga deposit, occurs in a large erupted mass of white feldspathic porphyry in small or irregular seams or impregnations. The mass of volcanic rock is much smaller than at Kosaga, though its extent is unknown. There are also numerous dykes of the same white feldspathic rock traversing the stratified rocks of the vicinity.

The ore is porphyry, more or less decomposed, and impregnated with sulphurets. It contains copper and iron pyrites, galena, argentite (?), etc., and more or less free gold. The ore is crushed with hoes, and concentrated, by washing, to one-fifth of its original weight. If too hard to be thus easily crushed, it is weathered for six months or a year. The washed ore contains about three and a half ounces of gold and seven ounces of silver to the ton of two thousand pounds, and about one per cent. of lead. The bullion value of one ton will thus be about eighty dollars; or of the unwashed ore, about sixteen dollars.

About half of the gold in the ore is obtained directly by careful washing. For this purpose the finest and richest portions of the jigged ore are washed by hand on the shallow wooden *ita*, or washing-board; and the gold thus obtained is added to the bullion in the last stage of the cupellation. The treatment is as follows:

1. Roasting of the washed ore in kilns.
2. Fusion of the roasted ore with lead in a low hearth.
3. Remelting of the slags and matte with lead.
4. Cupellation of the lead.

The bullion, which is two-thirds silver and one-third gold, is sent to the Innai silver mine and there parted. The product of the mine at the time of my visit, in 1874, was about 75 ounces of bullion per month.

Innai Silver Mine—Okatsu kôri, Akita ken.—This rich mine has been known and worked for over 250 years. At the time of my visit, in December, 1874, it was owned by the merchant Ohno.

* International Exhibition, 1876, Official Catalogue Japanese Section, p. 4.

During my stay, however, an officer arrived and took possession in the name of the government. It has since been turned over to the Mining Office; but is, I believe, still under Japanese management.

There are here quite a number of veins; but one only is worked, and little or nothing is known of the others. The one worked is a fissure vein, five to thirty feet in thickness, traversing strata, more or less metamorphosed, in an east and west direction. The dip of the vein is steep, from fifty to eighty degrees southward. The vein rock is calcite, usually quite crystalline.

The ore is quartz, through which the silver is disseminated in the form of argentite and antimonial silver, and contains also sufficient gold to form one per cent. of the bullion produced. The ore holds but little pyrite or other sulphurets, though the veins sometimes contain seams of blende. The ore-seams are from a few inches to three feet thick, the average being five to six-tenths of a foot. There is sometimes one such seam, and sometimes two, three, or five symmetrically arranged in the vein.

The ore, as mined, averages 130 ounces to the ton of 2000 lbs. This is crushed and hand-picked—not washed—to yield one and a half to two per cent. of silver, or 448 to 583 ounces to the ton. Small amounts of ore are sometimes found which will yield over five per cent., or about 1500 ounces of silver. Ore that, by hand-picking, cannot be made to yield 200 ounces, is either left in the mine or thrown on the dump. Thousands of tons of such ore, which, without dressing, would probably yield 80 to 100 ounces to the ton, would thus be available for treatment if a stamp-mill were erected.

As may be inferred from this fact, the process of treatment employed at this mine is extravagant and wasteful. This is occasioned by the extraordinary richness of the ore, which has made profit possible in spite of the most unskilful treatment, and has rendered effort after improved methods of working unnecessary. The process employed is as follows:

1. Roasting for agglomeration.
2. Fusion of roasted ore with lead.
3. Treatment of slags.
4. Cupellation.

Small quantities of ore, not more than two or three pounds, are treated at an operation—with large quantities of fuel and an energetic blast. The consequence is that fifty to sixty per cent. of the lead is sent up the chimney, carrying with it a large part of the silver. The small scale on which operations are conducted involves, more-

over, an unnecessary amount of labor, and adds largely to the expense of the treatment.

The mine is quite dry, and the Japanese miners have thus been able to extend their workings far below water-level—having reached, at the time of my visit, a depth of 750 feet below their lowest drainage-tunnel. To raise the water, however, a force of about fifty men and 274 pumps is required. The water is pumped in over a hundred lifts, each pump raising it less than eight feet. Although the amount of water so raised is small, it entails an expenditure of $250 per month—an amount exceeding the average monthly yield of most other silver mines.

This mine is one of the richest in Japan, and, when properly worked, will prove exceedingly profitable, and materially increase the bullion product of the empire. The yield of this mine in 1873 was 44,378 ounces, and in 1874* about 41,400 ounces of silver bullion. This bullion contains about one per cent. of gold, and five per cent. of base metals—one per cent. of copper and four of lead.

Ikuno Silver Mines—Asako kôri, Hiogo ken.—These were, at one time, probably the richest silver mines of the country. They were opened about three hundred years ago, and at the beginning of this century gave employment to some four thousand miners.† As the workings became deeper, the ore was found to be harder and more difficult to smelt, and the scale of operations was reduced, so that in 1869 only five hundred men were employed. It is at present worked by the Mining Office, and is under the superintendence of M. Coignet and a large staff of assistants. Mr. Nakano, my assistant, visited this mine last year, and the following description is based on his notes and on information derived from other sources:‡

The ore is calcite and quartz (?), containing silver mainly in the form of argentite, and occurs in veins one to three feet thick, traversing volcanic (?) rock. Associated with the argentite, specimens from the mines show gold, silver and native copper, blende, galena, copper and iron pyrites, malachite, smithsonite, and other minerals. The ore varies in richness from a few ounces to thirty or more to the ton. As it comes from the mine it is sorted, and the richer portions treated separately. Some of this rich ore is reported to yield as much as 1500 to 1800 ounces to the ton.

* Estimated—eleven months' yield being 38,014 oz.

† International Exhibition, 1876, Official Catalogue of the Japanese Section, p. 41.

‡ An excellent account of this mine was given last year in the Hiogo News.

The bullion produced contains seventy per cent. of silver, ten per cent. of gold, and twenty per cent. of base metal (copper). At the present value of silver, this bullion would be worth about $2.85 per ounce.

About half a million dollars have been invested in machinery. The ore is stamped dry, in a mill said to be capable of treating fifty tons per day. This is only partially finished, and not yet running at full capacity. The stamped ore is roasted with salt, and the silver extracted by barrel amalgamation. A part of the ore seems to be treated by a dry process, as I find mention made of smelting works, possibly Japanese. About five hundred miners are employed, and the expense of running the mine and mill is variously reported at from $15,000 to $30,000 per month. The accounts of profits are also conflicting; but there seems to be no reason why these should not be large, when the works are fairly started. The product of these mines in 1874 was 3236 tons of ore (of 2240 lbs.), but only about 62 tons were treated, yielding 1410 ounces of bullion, 1269 ounces of which was silver and 141 ounces gold.*

In June, 1875, at the time of my assistant's visit, the monthly yield was said to be 4416 ounces of bullion, showing a large increase of production.

Serigano Silver Mines—Takaki kôri, Kagoshima ken.—These mines are owned by a Japanese company, and are entirely under Japanese management. The working of them is chiefly interesting as showing how foreign methods may be adapted to the wants of the poorer mines of the country.

There are here three quartz veins, running about N. 55° E. through metamorphic rock, and dipping towards the southeast 30° to 36°. The largest of these veins varies between two and four feet in thickness; the second is two to three and a half feet thick; and the third is smaller, though the exact dimensions are not known. In the largest vein there are usually two seams of ore, one near either wall, each averaging one foot in thickness. In the second vein there is but one such seam, from eight-tenths of a foot to two feet thick. The third vein is not now worked.

The ore is cellular quartz, stained black by oxide of manganese, containing silver as sulphide. The vein-rock is quartz, sometimes white and massive, and sometimes cellular and stained black, like

* International Exhibition, 1876, Official Catalogue of the Japanese Section, p. 41.

the ore. The ore averages two and a third ounces of bullion per ton (of 2000 lb.). This bullion contains one-tenth of gold, and would be worth, at present, about $3 per ounce, making the value of one ton of ore about $7.

This very poor ore is treated in a rude stamp-mill and by barrel amalgamation, the process being modelled after that used at Ikuno. The ore is first crushed in two stamp-mills of eight stamps each, run by water-power. The stamps are of wood, shod with iron, and are quite light. The mortar is also of wood, with a small iron anvil in the bottom. The united capacity of these mills, when in good working order, is about one and a half tons of ore per day; but the average amount treated is little more than one ton.

The crushed ore, sifted by hand through forty-mesh sieves, is roasted with salt, about one and a half per cent. by volume, in shallow cast-iron pans. This roasting is continued for six hours over a wood fire. The ore is then cooled, transferred to barrels and amalgamated with a few pounds of mercury, one-half per cent. by weight of the ore treated. The barrels are revolved at a moderate speed from twelve to eighteen hours; and the charge is then run into a settling tank. Finally, the mercury is separated from the amalgam by straining and squeezing through several thicknesses of Japanese paper. The whole process is rudely, but still fairly well conducted; and I was able to suggest but few improvements.

The yield of the two mills is about three ounces of bullion per day; but on account of frequent stoppages for repairs, the monthly product averages only seventy-two ounces.

GOLD.

According to Japanese historians, gold was first found in Japan in the year 749 A. D., about eighty years after the discovery of silver. When we consider the frequency with which gold is brought to view in grains or nuggets by the natural action of running streams, and the ease with which it may be obtained by gravel-washing, while silver, on the other hand, but rarely occurs native, and requires a complicated metallurgical process for its separation, this commonly received statement, that gold was discovered at so late a date and after the discovery of silver, is certainly open to doubt.

During the ninety years in which the Portuguese exported gold from Japan in such large quantities, the gold mines must have been taxed to their utmost to keep up the supply. This export averaged

three and a third millions of dollars per year; and with the most ample allowance for the supply derived from the hoarded gold of centuries of non-intercourse, the annual yield of the mines must certainly have been more than two millions. It is also probable that the mines reached their maximum of production during this time; for so great a demand must of necessity have stimulated the supply. Indeed, we find partial confirmation of this supposition in the steady increase for a long period of the amount exported, which at one time reached the sum of twelve million dollars for a single year.

From our present knowledge of the character of Japanese gold deposits, it is evident that this great yield was obtained from placer workings. These, being shallow and of small extent, were quickly exhausted; and the attention of the miners was then turned to the quartz veins, which thereafter yielded small but more constant returns. When, however, the imperial edict of 1671 put a stop to the exportation of bullion, this exhaustion of the placers had hardly begun to show itself; for the annual exportation of the Dutch between 1649 and 1671 averaged nearly three millions, but little less than that of the Portuguese in the previous century.

The yield of gold in 1874 is estimated by Mr. Godfrey at 100 *kan*, about 12,000 ounces troy. From this we see that there has been a great falling off in the production of this metal. 12,000 ounces are worth but about $250,000—a very small portion of the average annual export of former times.

Gold occurs in about one-half of the ken and fu of Japan; but in most cases the deposits are not now worked. The records of the Mining Office show that permits were granted in 1874 for the working of fifty-eight gold mines. Of these mines I can learn of but six, worked solely for gold, which produced notable amounts of bullion; and of the six, three together produced, in that year, but fifty ounces. Most of the gold now comes from mines worked for silver. Five such mines have already been described.* Mines producing gold alone are, as a rule, not worth working.

Gold occurs in Japan in quartz veins and placer deposits, as well as in association with silver and other ores, as already described. The placer deposits are generally of fluviatile origin, and the gravel beds are thin and of limited extent. They are often found covering the terraces of the river valleys. These placer deposits are uniformly poor. The richest gravel found in Yesso yielded less than

* Vide, p. 282, et seq.

seven cents to the cubic yard; while the average of even the best field was only five and a half cents. From information gathered from various sources I infer that this is about the usual richness of similar deposits—even the most celebrated—in other parts of the country.

The quartz veins, as a rule, are also very poor. Rich quartz is found only in small and thin deposits. The usual yield is about one-third to one-half an ounce ($7 to $10 to the ton). In exceptional cases the yield may be as much as $90 or $100; but the veins are then so thin that the extraction of the ore becomes very expensive.

The methods employed in the separation of gold from the quartz of the veins and from the gravel of the placer deposits are exceedingly interesting. The method of extraction is, in either case, purely mechanical. The gold-bearing quartz is first crushed, and then ground with water, repeatedly and in small quantities, between heavy millstones moved by hand, until reduced to an impalpable slime. This, as it issues from the mill, is largely diluted with water, and conducted over a series of short and narrow boards covered with numerous diagonal saw-cuts. These boards, which collect the gold and other heavy metals very perfectly, are frequently cleaned in a tank; and the concentrated material so collected is washed with great care and skill on the board or *ita* of the gold-washers.

According to careful experiments made by the late Mr. Carlyle while in charge of one of the government gold mines, this process extracts, at the first working of the ore, sixty-five per cent. of the assay value, and the reworking of the slimes yields an additional fifteen to twenty per cent. Before the material is considered by the Japanese to be exhausted, it is treated a third time by the same process; bringing the proportion of gold saved to fully ninety per cent. of the assay value.

The method of washing employed in the working of the gravel deposits has already been described in my report on the gold-fields of Yesso. Briefly, it is as follows: Ditches are cut from convenient streams in such a way that the water flows over the bed-rock through the gravel deposit. A certain quantity of gravel is brought into the ditch by undermining the bank. The larger stones are carefully washed by hand and thrown out of the ditch, and the smaller ones separated with the aid of proper tools. The rapid current at the same time washes out the clay and fine sand, leaving a bed of fine gravel only in the ditch. When this has reached a thickness of about one foot, two or three small straw mats are placed

side by side in the bottom of the ditch near the head of the working; and the gravel, a little at a time, is hoed carefully over them. As the gravel is swept over the surface of the mats by the force of the current, the heavy gold and the iron sand sink between the thick twisted strands of straw, and are so retained. From time to time the mats are moved a few feet down stream, and the new material, exposed by their removal, is hoed over their surface in the same manner until finally all the gravel has thus been several times subjected to treatment. During the operation, the mats, as they become charged with gold, are taken from the stream and others are substituted. The concentrated material collected by the mats is finally washed with great care on the *ita*, or washing-board, for the separation of the gold.

Gold-fields of Yesso.—A description of some of the Yesso gold-fields, condensed from my report to the government, will serve to illustrate the general character of the placer deposits of Japan. Gold-bearing gravel is found on the island in many of the river valleys, apparently derived in every case from the metamorphic strata of the immediate vicinity. These deposits in each of the more important fields are found in the wider portion of the valley, where the river passes through some soft and easily eroded formation, and where a large reservoir has thus been formed to receive the gravel. Where the valley is wholly in metamorphic strata, it is, as a rule, quite narrow, and the deposits of gravel, though perhaps not poor, are of little value because of limited extent. Again, where in the gold regions the valley is entirely within the limit of the soft strata, the gravel will be composed chiefly of fragments of sandstone and shale, and will contain little or no gold.

These auriferous gravels everywhere afford unmistakable evidence of having been deposited in running water; and the direction of the old current, which can usually be determined from the position of flat stones in the beds, coincides, as a rule, with the general course of the present river valleys.

The most important gold-field of Yesso is in the upper valley of the Toshibets River, in the province of Iburi. The river here passes through the Toshibets series of clay rocks and tufas, and the valley is wide and deep. The gold occurs in the river gravel, and the deposits extend for a distance of five or six miles along the valley. The hills on either side are eight to nine hundred feet high, and a thousand to twelve hundred feet above the sea.

The bottom of the valley lies in three or sometimes four terraces,

which are about 12, 40, 85, and 260 feet respectively above the level of the stream. Each of these terraces is underlaid by clay rock, and represents a former bottom of the valley. They are covered by beds of gold-bearing river gravel, which are usually nine to twelve, but sometimes as much as thirty or forty feet in thickness. The gravel, in turn, is covered by yellow sand and loamy silt, usually only a few feet in thickness, but in the case of the highest terrace, fully fifty.

The gold is found to be concentrated in the lower layers of the gravel beds and next the bed-rock. This concentration is probably due to the repeated stirring and rewashing of the gravel as the old river shifted its bed from one side of the valley to the other. The richness of the gravel also increases very perceptibly as we ascend the stream—indicating the probable source of the gold. Numerous tests were made in different parts of the field by a modification of the Japanese method of gold-washing. In each case several cubic meters of gravel were treated. These tests yielded from 68 to 136 milligrams of gold per cubic meter of gravel washed, representing a richness of three to six cents per cubic yard. The average value of the gravel, for the whole field, would seem to be about three and three-fourths cents per cubic yard; and for the upper and more productive part of the valley, perhaps five and two-thirds cents.

On the Musa River, in Oshima province, is another large gold-field, similar to that of the Toshibets, but much poorer. The upper valley of the river is in metamorphic strata, and is quite narrow and deep, the hills on either side being several thousand feet high. The lower valley is in the soft strata of the Toshibets and Chingkombe groups—clay rocks and shales—and is quite wide, and surrounded by low hills. The transition from the narrow ravine to the broad valley is very abrupt, and marks sharply the line of junction between the hard and soft strata.

The gold-field comprises the upper five or six miles of the broader portion of the valley. The gravel covers the terraces and the bottom of the valley in regular beds averaging eight feet in thickness, varying between five and thirteen feet in different localities. As on the Toshibets, the gravel beds are everywhere covered with sand and silt, three to ten feet thick. The gravel is composed of pebbles of metamorphic rock; and, from its composition, seems to have been derived from the similar metamorphic rocks of the upper valley.

The results obtained from the washing of over a hundred tons of gravel from many different localities, show the field to be very poor.

The richness of the gravel varies between 8 and 32 milligrams to the cubic meter, though in one case we obtained 146 milligrams. Omitting this exceptional result, the gravel steadily decreases in value from the upper end of the valley to the lower. The average richness is about 16 milligrams to the cubic meter, or but three-fourths of a cent's worth of gold to the cubic yard.

Near Esashi and near Matsumai, in Oshima province, and near Kudo, in Shiribeshi province, are small gold-fields; but these are even poorer than the Musa field. Near Uragawa, in Hitaka province, and extending thence to the Tokachi River, in Tokachi province, is a large gravel formation, probably covering an area of over a hundred square miles, which in some places contains gold, but in infinitesimal quantity.

The remains of old workings are to be seen in all these localities, and it would seem that in former times the Musa and the Toshibets fields must have been extensively worked. Indeed, there is a tradition that about the year 1205 A.D., a party of several hundred miners from Chikuzen, a province of Kiushiu, came to Yesso, while the island was still in the hands of the barbarous and warlike Ainos, and worked the gold deposits of the Musa valley and other places in the vicinity. From data obtained in our survey of the Musa field, it appears that these old gold-washers must have obtained about $21,000 worth of gold from that locality alone; and, as they remained on the island thirteen years before they were massacred by the Ainos, they must have secured quite large amounts of the precious metal.

From the extent of the old workings on the Toshibets, this field also must, in former times, have yielded much gold; but there is in this case neither record nor tradition of the old workers. The Toshibets field was, however, worked in a small way about twelve years ago by the government of the Shôgun. A few men only were employed, and the total yield was quite insignificant and hardly paid the expense of working.

Kanaba Gold Mines—Okuzo, Akita kôri, Akita ken.—At the time of my visit, these mines were under the direction of Mr. Robert G. Carlyle, an engineer of the Mining Office. Since the death of Mr. Carlyle, the mine has been under the superintendence of Mr. R. J. Frecheville, of the same office.

These gold mines have been worked for many centuries, and hundreds of tunnels and adits penetrate the hills in every direction. A number of these old workings have been reopened and surveyed.

Tunnels over two miles in length have been found, and drifts and stopes innumerable—all driven with imperfect tools, before the time of gunpowder; and affording, especially in the carefully dressed walls and squared corners of some of the larger tunnels, evidence of slow and patient labor. One of these tunnels is said to have been the scene, many years ago, of a desperate hand-to-hand fight between the rival miners of two provinces, whose workings, driven from opposite sides of the mountain, met in this place. The connecting winze was afterwards blocked up, and has been only recently re-opened, for ventilation.

The gold occurs in small veins, traversing a porphyritic rock. The veins vary in thickness from three feet to a mere sheet. The gold is associated with copper and iron pyrites, blende, and galena. The thin veins contain the richest ore, while the larger veins are usually too poor to be worked. These large veins contain copper and lead, but neither are they rich enough in these metals to be worked. The large fissures are quite regular; run north and south, and dip from 45° to 70° W. They are usually filled with decomposed porphyry, often in the form of a plastic clay. The copper ore occurs in local deposits of a limited extent near the foot-wall.

The large veins intersect and cut off the smaller gold-bearing veins; these latter being either branches of the main fissures, or faulted to a considerable extent by them. Mr. Carlyle was inclined to adopt the former view. There seems to be little parallelism between these smaller gold veins, though the general direction is about east and west.

The average richness of the ore, as handpicked and prepared for treatment by the Japanese process, is about $90 dollars per ton (containing 4.4 ounces of gold). Forty miners produce, of such ore, only about one-third of a ton per day. Including all expenses, the cost of mining reaches nearly $38 per ton (of 2000 lbs).

A ten-stamp mill, of the California pattern, with a capacity of fifteen tons of ore per day, has been erected by the Mining Office. At the time of my visit it was not finished, but has, I believe, since been put in operation. In working the mine on the scale necessary to supply this mill, the cost of getting out the ore will be greatly reduced; but, at the same time, it will be impossible for the miners to select, as heretofore, the best places and the richest mineral. The average richness of the ore mined will not probably be more than $20 per ton, if indeed it reaches that figure. The cost of treatment by the Japanese process is but $8.65 per ton of 2000 lbs., and by the

stamp-mill will probably be much less; so that the question is whether the cost of mining, now so large, can be reduced to a figure that will permit a profit. The solution of this problem will perhaps determine whether any of the gold deposits of the country can be worked with profit; for this Okuzo mine, though perhaps not the richest, is better than the average of Japanese gold mines. We shall, therefore, await with interest the result of this experiment.

Yamagano Gold Mines—Kuwabara kôri, Kagoshima ken.—These mines are owned and worked by a private corporation, the Satsuma Mining Company. A fifteen-stamp mill, built in France, and originally ordered, I believe, by the advice of M. Coignet, is being erected here, under the superintendence of a Japanese machinist from the Ikuno mines. The mill will be run by a large turbine, and will treat 24 tons of ore per day.

There are several mining districts in this vicinity. The mines of Nagano, in the neighborhood of the mill, are at present flooded, and work has been suspended, pending the completion of a new drainage-tunnel. This, with its branches, it is said, will be about two and a half miles in length, and will require thirty years for its construction. The mines which will be drained by this tunnel are reported to be very rich.

In the meantime the supply of ore is drawn from the mines of Yamagano and Musoyama. The gold occurs in quartz veins traversing a stratified tufa rock. This tufa, which is quite soft, alternates with a hard, dark-blue crystalline quartzite, and in the vicinity are beds of sandstone and shale. Both the quartzite and the shales contain in places leaf-prints of maples and other deciduous trees. The strike and dip of the gold-bearing veins correspond usually with the strike and dip of the stratified rocks, and they are apparently bedded veins, though without doubt true fissures. The general direction is east and west, the dip towards the south.

At Yamagano the veins are rarely more than one-tenth of a foot in thickness, and when thicker, are too poor to work. The average yield of the ore is about three-tenths of an ounce, or six dollars to the ton of 2000 pounds, which, it is said, does not pay expenses.

At Musoyama there is a vein five to six feet thick, filled for the most part with fragments of wall-rock, cemented by thin seams of gold-bearing quartz. The yield of this ore is nearly one-half of an ounce of gold, or $9.70 to the ton. As the vein is so exposed that it can be quarried in the open air, twenty-five workmen, mostly boys, produce six tons of ore per day. At another mine, Yamanokami-

yama, small quantities of ore are obtained, which is said to yield 1.58 oz., or $28.80 to the ton.

At both Yamagano and Musoyama there are large deposits of gravel containing gold quartz. These deposits are washed for gold and the quartz picked out by hand. One cubic yard of this gravel yields about eleven cents worth of gold by washing, and the quartz picked out, when crushed and treated by the Japanese process, yields about as much more.

Sado Gold and Silver Mines.—The mines of the island of Sado are said to be the richest and most valuable in Japan. They have been worked for more than a thousand years, and formerly yielded much gold. The bullion produced by the mines at present is mostly silver, gold occurring in small proportions only. It would seem proper, therefore, to class the mine among those of silver. They are now in the control of the Mining Office, and under the superintendence of Mr. Alexis Janin.

From a short account of the principal mines given by Mr. Gubbins, of the British Legation, in a paper read before the Asiatic Society, in April, 1875,* I extract the following details:

The mines are situated near Aikawa, towards the southern extremity of the island. The old workings, which are very extensive, are of the most primitive kind, and the mines have, for the most part, been abandoned for want of means to control the water. About sixty years ago three hundred miners are said to have lost their lives by a sudden flooding of one of the principal mines, perhaps caused by the accidental tapping of a large body of water collected in some older working.

Of the character of the deposits, the richness of the ores, and the nature of the work now going on, Mr. Gubbins gives no information. He mentions a little episode, however, which illustrates the difficulty sometimes attending the introduction of labor-saving machinery and new methods of working. It seems that a few years ago a tramway was constructed to bring the ore from the mine to the works. Its use, however, has recently been discontinued, because of difficulties of working, frequent accidents, etc., and it proves better policy and quite as economical to employ women at four cents a day to carry the ore on their backs.

The principal problem at present is to drain the mines and put them in proper working order. It is estimated that it will take five

* Trans. Asiat. Soc. of Japan, vol. iii, part ii, p. 96.

years and a considerable outlay of capital to accomplish this. There is, however, ore enough on hand to keep the new smelting works* running for two years. In the meantime, for various reasons, the mines are being worked at a loss. This is in part due to the unproductive work now carried on, and in part to the Japanese system of administration. In one year bullion to the amount of $60,000 was sent to Tokio from the mines, but the expenses (in part capital invested?) for the same period were $75,000.

From the catalogue of the Japanese section I extract the following additional details:†

The ore occurs in two large veins running north and south. These veins divide into a number of smaller branches, which alone were worked in former times. Of the many old adits, but six are in working order; these follow veins from three to twenty feet thick. The ore contains gold, silver, copper, lead, and in some places antimony.

It is proposed to sink three shafts, two for hoisting the ore and one for pumping and hoisting combined. One shaft is to have a depth of 668 feet, with four horizontal galleries 2000 feet long, at intervals of 100 feet. Another shaft will be 902 feet deep, with three galleries 2500 feet long. The whole work will be completed within 12 years. It has been estimated that 300,000 tons of ore will be obtained in this time, and in the three years following an average of 60,000 tons per year.

At present the whole of the ore mined cannot be treated, as the smelting works are incomplete. In 1873 fully 60,000 tons remained from the working of former years, and during the same year an additional amount of 1867 tons was produced. Of this but 1217 tons were treated, producing 24,549 oz. of silver and 592.27 oz. of gold, which would be worth at present prices of bullion about $40,000. The ore would thus seem to average nearly $33 per ton (2240 lb.?), and to be rather an ore of silver than of gold.

TIN.

Tin is found in but three of the thirty-five ken of Japan. According to Mr. Godfrey, the total yield in 1874 was 16,800 pounds. In the same year four permits were granted for tin mining. In two of these tin was apparently of secondary importance, being associated in the one case with copper and in the other with lead.

* Query: stamp-mill also?

† Official Catalogue, Japanese Section, Phila., 1876, p 41.

Tin occurs in Japan, so far as I know, only in veins, though in 1874 two permits for exploration were granted to parties who claimed to have discovered deposits of stream tin.

Taniyama Tin Mine—Taniyama kôri, Kagoshima ken.—Nearly the whole of the tin produced in Japan is from this place. The mine is said to be owned by the Prince of Satsuma, but is under the control of the company that works the Yamagano gold mines. There are twenty-one distinct veins of tin averaging one and a half feet in thickness, but varying from a few inches to four feet. These veins traverse a series of sedimentary rocks similar to the formation at Yamagano, composed of soft tufas, shales, and sandstones, with occasional beds of hard, dark-blue quartzite. The surface is almost everywhere covered with a deposit of modern pumice, and exposures of volcanic rock are of common occurrence.

The general direction of the veins is northwest and southeast, while the strike of the rocks is northeast and southwest, sometimes approaching an east and west direction. The veins are sometimes bedded between hard and soft strata, but usually traverse both. The ore is cassiterite, found in almost microscopic crystals scattered through a gangue of quartz. As mined, the average richness is 12 to 13 per cent. of tin, though specimens of nearly pure cassiterite are occasionally found. One rich specimen, assayed by one of my students, yielded 56.7 per cent. of metallic tin. The ore is crushed, and is ground between millstones in the same manner as ores containing gold. It is then concentrated by washing on the *ita* to a richness of about 50 per cent. The first grinding and washing yields about 15 per cent. of concentrated ore; the second, 5 per cent.; the third, 2 per cent.; and the final treatment, after two years' exposure to the weather, one-half of 1 per cent. The boards used for washing are similar to those used in the treatment of gold. They are of circular form and very shallow, 2.2 feet in diameter and 0.08 feet deep. This elaborate system of concentration is very expensive, requiring for the treatment of a single ton more than eighty days' work, nine-tenths of which is expended in the slow and laborious washing of the ore, a little at a time, on these wooden pans.

The washed ore is treated by the following process:

1. Roasting of the ore in kilns.
2. Fusion of roasted ore in low hearths.
3. Remelting of tin, in an iron kettle, for purification.
4. Washing and remelting of slags.

In the case of impure ores, the first roasting is sometimes repeated.

In the fusion on the low hearth the ore is charged between dampened layers of old straw matting, and the operation is conducted with great care to avoid mechanical loss of fine ore. The slags from this operation and from the refining of the tin are quite pasty, and contain much metal in fine grains. They are crushed and washed before remelting. The final refining of the tin is a simple remelting, though the surface is kept covered with fine charcoal to prevent oxidation.

The mine and smelting works give employment to about 120 men and boys. They are paid by the amount of tin produced, about sixteen cents per pound, partly in rice and partly in money. The yield of the mine, at the time of my visit, was said to be over 2500 pounds per month. At this rate the production would be fifteen to sixteen tons a year, nearly double Mr. Godfrey's estimate for the whole country. The statement, however, can hardly be correct, for the average daily earnings of the workmen would, at this rate of production, be fully double the wages ordinarily paid in this part of the country. From another source I learn that in 1870 the product was eight tons, which is probably nearer the average annual yield of the mine.

ANTIMONY.

Antimony is reported to occur in six of the ken of Japan. Four mines were producing ore in 1874, but only in small quantity. No ore has, to my knowledge, been smelted in the country, and small shipments only have been made to England and elsewhere on speculation. I visited one of the most important localities, that of Takehama, on the island of Amakusa, but found the deposit quite insignificant. The stibnite occurs in small and irregular veins, quite pure and free from gangue, and in seams one inch to one foot thick. The country rocks are hard sandstones and dark-blue shales. There were at work three or four miners, who had several tons of dressed ore on hand awaiting the orders of their agent in Nagasaki.

MERCURY.

According to Mr. Plunkett, cinnabar occurs in two localities, but neither of these deposits is now worked. One mine in the northern part of Nippon is said to be very promising, but the present proprietors are not now inclined to expend money for its development. The other mine is near Ainoura, on the peninsula of Hirado (not on the island of the same name), in Matsûra kôri of Nagasaki ken. Mr.

Gower, who formerly superintended the working of this deposit, reports it to be valuable. The mine was opened under his direction some years ago, and a retort furnace was erected for the distillation of the metal from the ore. The furnace was worked successfully, and mercury was produced in some quantity. During the absence of Mr. Gower, however, the workmen, by careless firing, melted the iron retorts, and discouraged by this accident, the owners decided to abandon the undertaking.

The cinnabar occurs here as a local impregnation in sandstones of the coal measures, and filling small seams and fissures in the rock.

SULPHUR.

As might be expected from the volcanic nature of the country, deposits of sulphur are of common occurrence in Japan. It is found in no less than seventeen different ken, and in four of the provinces of Yesso. It occurs usually in superficial deposits in the craters and on the flanks of inactive volcanoes, and in solfataras. A small quantity is also found deposited from the water of certain hot springs.

In 1875 about six hundred and seventy tons were exported from Hakodate, Yokohama, Hiogo, and Nagasaki. The annual production of sulphur, making allowance for that consumed at home, and that sent abroad from other ports, must be much more than this. In 1874 there were twenty-one productive mines, and three permits for exploration were issued by the Mining Office.

A description of the sulphur deposits of Yesso will serve to illustrate the manner of occurrence of sulphur in Japan. These deposits have been examined and described by Mr. Lyman, and the following notes are condensed from his reports:*

Superficial incrustations, where the sulphurous fumes continually escaping from fissures in the mountain condense in the cooler earth, and volcanic scoriæ of the surface, are found near the tops of three volcanoes, viz.: Esan, in Oshima province, Tarumai, in Iburi province, and Iwaonobori in Shiribeshi province. The richer portions of the sulphur-bearing earth yield about forty per cent. The sulphur is extracted by heating the earth in iron kettles, and is afterwards purified by repeated meltings in the same vessels. The beds are quite thin, and the amount of sulphur in sight is small. Mr. Lyman estimates the available amount of sulphur at these places at

* Kaitakushi Reports, 1871 to 1875, pp. 5, 143–148, 470–473.

about 140 tons. At the time of his visit the deposit at Esan was alone being worked. Remains of old furnaces, however, were seen at the other places. The yield at Esan was about sixteen tons per year, though the work was carried on only in the three summer months. The expense of working was very large, and, according to Mr. Lyman's data, the sulphur was produced at a large pecuniary loss.

Superficial deposits are also found in Horobets kôri, in the province of Iburi, at Nuburibets, and at Oi Lake in the immediate vicinity. At Nuburibets the sulphur is found in a small valley about 900 feet above the sea. Oi Lake is a large pool of boiling water, one-quarter of a mile wide, apparently occupying an old crater. The sulphur is found on the banks of the lake. Mr. Lyman estimates the amount of sulphur at these places at 100 and 35 tons respectively.

Bedded deposits of sulphur occur at Kobui, in Oshima province, not far from the volcano of Esan, and about twenty-seven miles east of Hakodate. Most of the sulphur here is of a peculiar gray color, and for this reason though quite pure is not merchantable, and has not yet been mined. A bed of yellow sulphur was found in the same vicinity, but has been exhausted. The beds appear to have been deposited from sulphur waters, and are probably of small extent. The bed of yellow sulphur was one foot thick, and was followed by a drift for a distance of two hundred and forty yards, when it became too poor to be worked. The gray sulphur occurs in a bed twelve feet thick, exposed for a distance of one hundred feet. There are also exposures of smaller beds, two feet and four feet in thickness, of unknown but probably small extent.

The most remarkable deposit of sulphur in Yesso is that of Itashibeonai, in Shari kôri, in the province of Kitami, near the northeast extremity of the island. The sulphur is found in a small valley about two miles from the coast. An area of about eight acres on the slope at the head of the valley is covered with a superficial deposit of sulphur, averaging six inches in thickness. In the centre of this deposit, about one hundred feet lower than the top of the ridge, is a large cavity, one hundred feet in diameter and thirty feet deep, from which clouds of sulphur fumes are continually rising. These condense, and the sulphur is distributed over the surrounding earth. In the bottom of this cavity is a small crater, twenty feet by fifteen, apparently filled with melted and boiling sulphur of a dark

brownish-gray color, through which gas and fumes of sulphur are continually escaping with great violence.

Mr. Lyman estimates the sulphur in sight, on the surface of the ground, at 3200 tons. He suggests, moreover, that an almost inexhaustible supply might be obtained from the crater by means of a proper derrick with a dredgelike scoop, "or perhaps by means of a pump."

RÉSUMÉ.

But few countries are better supplied with coal than Japan, which mineral is in our day the main source of national power and prosperity. Coal, as the principal generator of steam, moves the machinery which so largely multiplies the power and the usefulness of human labor, and transports the products of the soil and of industry by land and by sea; coal aids in the extraction of the useful metals from their ores, and gives us heat, light, and other comforts of civilized life. It has been estimated that the coal product of Great Britain is equivalent to the labor of one hundred and thirty-three millions of operatives working without-wages for her enrichment.* So it may be said of Japan, that in the Ishikari coal-field alone there is stored up, and available for at least two centuries' use, the labor of an equal body of men. To secure the full advantage of this store of fuel a supply of iron is necessary, for in the construction of the machinery by which the power of steam is utilized, no available substitute for this metal has been found. It is therefore fortunate that rich deposits of iron ore of the finest quality are so abundant.

Next in importance, perhaps, to coal and iron, are the porcelain clays, which form the basis of a very important industry. The deposits of sulphur, also, are by no means unimportant.

Of metallic minerals other than iron, ores of copper and silver alone occur in considerable quantity, and in deposits that can profitably be worked. Lead and gold are found in many parts of the country, but the deposits are almost always poor, and not worth working. Tin and mercury are of rare occurrence, while other metals, such as antimony, cobalt, etc., occur only in unimportant deposits.

The mineral wealth of Japan therefore lies, not as was formerly supposed in inexhaustible deposits of the precious metals, but chiefly in its abundant stores of coal and iron.

On Plate V is a map of Japan, prepared to show the principal mining districts, coal-fields, etc.

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* J. S Newberry, Report of Progress, Ohio Survey, 1869, p. 23.

COST AND RESULTS OF GEOLOGICAL EXPLORATIONS WITH THE DIAMOND DRILL IN THE ANTHRACITE REGIONS OF PENNSYLVANIA.

. BY LOUIS A. RILEY, ASHLAND, SCHUYLKILL COUNTY, PA.

I DESIRE to submit, for the consideration and information of the members of the Institute, the following data, drawings, and tables, showing what I believe will be interesting information with regard to the diamond drill, and its uses in developing mineral lands.

I would first say that the results given have been obtained during the past two years by means of two drilling machines belonging to the Lehigh Valley Coal Company, operating on their coal lands in the Mahanoy, Lehigh, and Wyoming regions.

1st. A tabulated statement, giving location of borings, date, progress, total cost, itemized cost per foot, etc.

2d. Section showing strata bored in Nos. 5 and 10 holes at Mt. Carmel, see Plate VI.

3d. Section showing strata bored in No. 19 hole at Hazleton, see Plate VI.

4th. Photograph and description of drill No. 2.

From the first it will be seen that the total number of test-holes bored up to May 1st of this year is 24; 9 of these are in the Mahanoy region, 6 in the Lehigh region, and 10 in the Wyoming region, in all of which cores have been taken for the whole distance. The total distance bored is 9902 feet. The majority of the holes have been put down for the purpose of proving the lower veins of the coal series, and have had to encounter the harder rocks of the coal formation. Much of the distance has been through the lower conglomerates, going in some cases through the coarse egg conglomerate, the foundation of the coal deposit, and to the green sandstone and red shale which underlie it. These lower sandrocks and conglomerates are among the hardest known to geologists, and present a formidable resistance to the exploring drill. This fact must be taken into consideration in comparisons of cost of drilling, and when considered will still further improve the very favorable results I am able to show in my statement of costs. In illustration, I will cite the work of one bit when boring in the upper or softer rocks of the Wyoming region, where 280 feet were obtained without resetting, while in the Lehigh and Mahanoy regions, in the lower and harder rocks, bits set with the same quality of diamonds would only bore from 3 to 20 feet before being worn out. In this connection it may

be of interest to note the relative average distances from the Mammoth or Baltimore Vein to the red shale or green sandstone in the three regions, also the conglomerate rock found.

Region.	Dist. Mam Vn to red shale.	Amt Conglom.
Mahanoy,	1200 feet.	840 feet.
Lehigh,	490 "	190 "
Wyoming,	650 "	300 "

In the Mahanoy and Lehigh regions the coarse hard conglomerates predominate, while in the Wyoming they are of a softer and finer texture.

We have two drills in constant use. No. 1 is the smaller and is the ordinary pattern used by the Pennsylvania Diamond Drill Company. This drill is run by a Root square engine. No. 2 (see accompanying cut), is of an improved design of large size, with oscillating engine of fifteen horse-power, and performs its work in a highly satisfactory manner. During the past year it has drilled 9 holes of a total length of 4562 feet, without being once repaired, or incurring any cost outside of the ordinary running expenses. The deepest hole bored was 900.6 feet, so that we have not yet had an opportunity to test its capacity of 2000 feet as given by the builders, Messrs. Allison & Bannan, of Port Carbon.

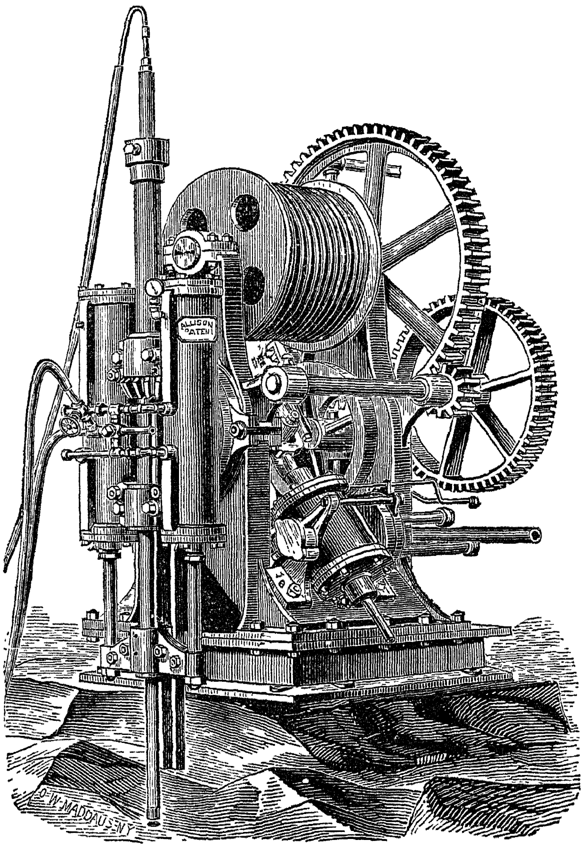
The cost of the drill, with movable boiler, 16-horse power, and 1000 feet of two-inch drill rods, was $3872.40. In addition to drill, boiler, and rods, our outfit, with each drill, comprises a set of machinists' and firemen's tools, a portable house, and a stock of diamonds sufficient to keep about five bits set for each machine, making a total cost of each drill and outfit of about $5000.

Our portable house is a great improvement on the temporary sheds put up by the Drill Company. It is 16 feet square, built in sections of 8 feet by 3 feet, the frame, sides, and roof being fitted and held together with hooks; it can be taken down and put up by two men in one day, and affords a perfect protection from the weather and from trespassers.

Our labor force consists of a foreman, an engineer, and a fireman with each drill, and an assistant superintendent in charge of both drills, or as many more as may be added. If it were not for the work and time of removing the rods, once for about every ten feet of boring, to obtain core, two men would be ample, but as it is, I find three men do the most work at the least cost per foot.

It is not necessary for me to state the value of the diamond drill for exploring work, as that is probably known to all the members of

the Institute; it may be of interest, however, to know the method we employ for obtaining the most reliable information, and of putting it to practical use in our mining operations.



IMPROVED DIAMOND DRILLING MACHINE, WITH ALLISON'S PATENT HYDRAULIC FEED.

Steam cylinders (oscillating), 6 inches diameter, 6 inches stroke, central spindle, 3 inches diameter, can be fitted to take rods from $1\frac{5}{8}$ inches up to $2\frac{1}{4}$ inches diameter. Hydraulic feed cylinders, 5 inches in diameter, 2 feet run, improved hinged swivel-head swings to one side, out of way of drill-pipe. Spiral-grooved hoisting drum, 20 inches diameter, 16 inches long, grooved to take $\frac{5}{8}$ or $\frac{3}{4}$-inch wire rope; drum double-geared, so as to hoist heaviest rods with single rope. Reversing valve on engine, so as to hoist and lower at will.

Weight of machine set up complete, ... 3486 lbs.

" " without drum-gear and swivel-head, . 2195 "

Will drill a 2-inch hole 2000 feet deep.

If our purpose is to develop the position and size of any coal vein, or series of veins, we select such a point, either on the surface or inside the mines, as we think, from what data we have, is most likely to give the desired information. The solid rock is then exposed, the dip taken, and a stand-pipe set. The drill is then set up, the house erected, etc., and the work begins. The hole may be level, or perpendicular, or at any angle between; it is better, however, that its direction should be at right angles with the measures, as this gives the shortest distance, and the core is less broken. As the work proceeds the core is removed and stored in long boxes, in the order in which it is bored. A minute record is kept by the foreman of amount and rate of progress, kind of rock, dip of strata, steam and water pressure, delays and causes, etc. Samples of the changes in the strata, with all the coal core, are retained, labelled, and stored in boxes, at the company's office, for future reference. Drawings are then made, one showing the strata in detail, and the other a cross section through the basin, or locality of the boring. The first, generally on a scale of 30 or 60 feet to 1 inch, such as the section of the boring at Hazleton, submitted herewith (see Plate VI); the second, on a scale of 100 or 200 feet to 1 inch, as the section at Mount Carmel, also submitted. One of the great defects of the diamond drill method, heretofore, has been a want of certainty as to the direction of the inclination of the strata as shown by the cores. We could tell, with reasonable exactness, the amount in degrees of the dip, but as to the point of the compass we had to judge from indications outside the bore-hole. This defect, we think, has been satisfactorily overcome, in a device of Mr. Thomas C. Nash, our assistant superintendent, called a pitch indicator. It is an attachment to the drill, by which the last piece of core which remains unbroken from the bed-rock, when the drill stops, is brought to the surface in the same position as when broken off, by the rods being raised by the hydraulic pressure. If this piece of core is marked by a seam in the strata, the dip and direction can be obtained accurately.

The accompanying table gives some interesting details with regard to cost, rate of boring, etc.:

The total length of 24 holes bored is	9901.9 feet.
The average progress per day is	18.9 "
The average cost per foot is	$2 22

This includes labor, diamonds, fuel, water, supplies, repairs, expense of moving from place to place, etc., in fact, everything except

royalty for use of patent right, and interest on investment and wear and tear. The last two items I estimate to be 20 cents per foot.

The average cost per foot for labor is	. . . . .	$1.15
" " " diamonds,	. . . .	0 66
" " " supplies, repairs, etc.,	. .	0 41

Our deepest holes I find to be the cheapest per foot; 8 of the number have been over 500 feet in depth. Leaving out the first two for the purpose of comparison, as these two cost more than the rest by reason of being the first, I find the average of the deep holes to be per foot $1.95, while the general average without the first two is $2.10 per foot.

The diamond account has been a very difficult one to determine, owing to the fact that the same diamond is used over and over again in different holes, gradually depreciating until it becomes ground up into fine dust, or too small to set either in the bits or core barrels.

Our diamonds are bought in the quantity, the borts or real diamonds of light color, costing $11 per carat, and the carbons of dark color costing $9 per carat. The bits are set with these diamonds, 5 of each kind, weighing on an average about 18 carats per bit. When a bit is set with new diamonds, and sent out, if it was charged to the hole using it, that hole would be paying for diamonds that would still be of use in other holes, and consequently our first holes would pay for all the diamonds. To get over this difficulty, as it was impossible to keep track of every individual diamond, I found it necessary to adopt some percentage to charge for loss. I had no data for this, other than the results of our own work, and to get it, the weights of diamonds in each bit, before using and after, were carefully noted, and amount of dust or fragments obtained. This being done with several bits, I found the depreciation in diamonds to be about 22 per cent., and to allow of some margin, I assumed it to be 25 per cent., or, in other words, the value of the diamond was gone after being reset 4 times. I have recently revised this estimate, with the results given from the use of some 120 bits, and from an inventory of diamonds and dust on hand, I find that I had previously overestimated the loss somewhat, that 18 per cent. was nearer the mark.

The costs per foot given in the table, on the basis of twenty-five per cent., are therefore slightly greater than the real amounts. I now assume the loss to be twenty per cent. and charge each hole with that percentage of the value of each bit used on it.

No of hole.	Location.	Date of Boring. Began.	Date of Boring. Completed.	No of drill.	Diameter of Hole.	Diameter of Core	Length of Bore-Hole: Stand-pipe.	Length of Bore-Hole: Boring	Length of Bore-Hole: Total.	Progress per day, 10 h'rs: Average.	Progress per day, 10 h'rs: Maximum	Total cost	Cost per Foot. Labor.	Cost per Foot. Diamonds	Cost per Foot. Fuel, water, repairs, etc	Cost per Foot. Total.	Cost per Foot. Interest	Cost per Foot. Total.
	PENNSYLVANIA.				in.	in.	feet	ft in	ft in.	ft in	ft in							
1	Delano, Schuylkill County.......	April 14, 1874	June 11, 1874.	1	2	1½	13 0	501 8	514 8	10 1	20 0	$1998 90	$1 63	$0 97	$1 28	$3 88	$0 20	$4 08*
2	Hazleton, Luzerne County. . .	July 1, "	Sept 26, "	1	"	"	8 0	682 0	690 0	9 3	36 7	2189 43	1 63	1 14	0 41	3 18	0 20	3 38
3	Ashland, Schuylkill County . .	Oct. 13, "	Nov 6, "	1	"	"	26 3	344 4	370 7	14 8	34 0	957 19	1 41	0 79	0 38	2 58	0 20	3 78
4	" " "	Nov. 24, "	Dec 8, "	1	"	"	20 4	258 7	278 11	13 9	26 9	941 62	1 60	1 36	0 41	3 37	0 20	3 57
5	Mt Carmel, Northumberland Co	Jan. 15, 1875.	Mar. 5, 1875	2	"	"	23 0	877 6	900 6	15 3	28 3	2187 74	1 51	0 56	0 34	2 41	0 20	2 61†
6	Mahanoy City, Schuylkill Co....	Dec. 30, 1874.	Feb 27, "	1	"	"	23 0	350 10	373 10	7 2	20 0	1512 35	1 99	1 57	0 48	4 04	0 20	4 24‡
7	Montana, Columbia County . .	April 16, 1875.	June 5, "	2	"	"	62 0	655 5	717 5	14 9	33 9	2123 90	1 64	0 76	0 55	2 95	0 20	3 15†
8	Mahanoy City, Schuylkill Co. ..	Mar. 21, "	April 7, "	1	"	"	30 9	250 10	281 7	19 3	33 7	795 00	1 25	0 94	0 63	2 82	0 20	3 02
9	" " " " . .	June 2, "	June 9, "	1	"	"	41 0	122 11	163 11	17 6	23 4	572 10	2 29	0 49	0 73	3 51	0 20	3 71
10	Mt Carmel, Northumberland Co.	June 28, "	Aug 27, "	1	"	"	27 0	695 10	722 10	13 2	24 0	1216 03	0 85	0 40	0 43	1 68	0 20	1 88
11	Pittston, Luzerne County	July 1, "	July 26, "	2	"	"	1 1	462 7	164 5	21 1	42 5	699 47	0 80	0 39	0 32	1 51	0 20	1 71
12	" " "	Aug 5, "	Aug. 20, "	2	"	"	1 8	366 1	367 9	26 3	44 9	493 26	0 82	0 36	0 17	1 35	0 20	1 55
13	" " "	Sept. 3, "	Sept. 7, "	2	"	"	18 0	80 0	98 0	20 2	25 3	205 00	1 09	0 73	0 27	2 09	0 20	2 29
14	Hazleton, " " . .	" 13, "	" 17, "	1	"	"	10 0	150 0	160 0	30 0	53 0	245 55	0 88	0 25	0 40	1 53	0 20	1 73
15	Pittston, " "	" 13, "	Oct. 9, "	2	"	"	1 8	509 7	511 3	21 3	33 5	501 15	0 59	0 28	0 11	0 98	0 20	1 18§
16	Hazleton, " "	" 24, "	Sept. 29, "	1	"	"	11 6	139 3	150 9	27 8	39 2	288 40	0 97	0 47	0 47	1 91	0 20	2 11
17	" " "	Oct. 6, "	Oct 15, "	1	"	"	16 6	126 0	142 6	15 9	23 8	334 69	0 97	0 71	0 59	2 27	0 20	2 47
18	Wilkesbarre, " "	" 22, "	Nov 27, "	2	"	"	0 0	536 3	536 3	17 3	28 5	832 19	0 78	0 45	0 32	1 55	0 20	1 75
19	Hazleton, " "	" 27, "	Dec 18, "	1	"	"	16 0	624 0	640 0	33 7	32 8	1370 30	0 88	0 73	0 53	2 14	0 20	2 34
20	Pittston, " " . .	Dec. 9, "	Jan. 29, 1876	2	"	"	12 5	334 9	347 2	16 8	24 0	563 12	0 94	0 50	0 18	1 62	0 20	1 82
21	Hazleton, " "	Jan. 17, 1876.	Feb. 19, "	1	"	"	7 0	473 4	482 4	16 1	33 3	1216 17	1 12	0 89	0 52	2 53	0 20	2 73
22	Pittston, " " . . .	Dec. 31, 1875	Jan 17, "	2	"	"	18 7	303 3	321 10	23 9	28 4	322 24	0 65	0 20	0 15	1 00	0 20	1 20
23	" " "	Feb. 9, 1876	Feb. 25, "	2	"	"	27 0	350 0	377 0	26 9	29 4	396 58	0 67	0 22	0 16	1 05	0 20	1 25
24	" " "	Mar. 3, 1876.	Mar. 18, "	2	"	"	8.0	280 5	288 5	20 6	46 3	385 20	0 59	0 60	0 15	1 34	0 20	1 54
	Total.							9901 9										
	Average.						..	......	......	18 9 ft	..	....	$1 15	$0 66	$0 41	$2 22	$0 20	$2 42

* Coarse conglomerate; had to haul water.
‡ Delayed with frozen water-pipes.
† Preparatory shaft, deep and expensive.
§ Cheapest hole.

THE NOMENCLATURE OF IRON.

BY DR. HERMANN WEDDING, BERLIN, PRUSSIA.

I ASK your permission to speak about a matter which is not of a specifically scientific nature, but more of a general—I might even say of an international—nature, and the international character which this city now presents must be my justification for introducing it. The Germans, very often, are thought to be an exceedingly warlike people, but I come to-day in the capacity of a peacemaker. Our German language is an original language; it is, therefore, a language in which it is impossible to change the meaning of a word at will. It may be, perhaps, easier in a combined language, as the English, to associate and to exchange meanings. Now, a word which we hear a great deal at the present day, is "*Stahl,*" in English, "steel." This word means, in the German language, a substance which can be hardened. As the German literature, in relation to metallurgy, is the oldest of the modern world, this circumstance may give the German a right to ask for consideration. But I think, now, when the four languages, German, Swedish, French, and English, compete in rich metallurgical literature, it is very necessary to have uniformity in the nomenclature of iron, which would prove not only useful for science, but equally so for trade. For that purpose I propose to make the divisions of iron so that the word steel shall comprise a subdivision and not a primary division as formerly.

Nature furnishes us iron mostly in the state of oxides, and if in any other condition, we must convert the ore into oxide before we can make iron. The oxides are always mixed with certain earthy substances called rock or gangue. The extraction of iron involves, therefore, the twofold process of the reduction of the iron, and imparting to it the amount of carbon necessary for technical purposes, and the separation of the reduced and carburized iron from the gangue. The reduction is always effected by carbon or carbonaceous substances (coke, anthracite, carbonic oxide, etc.), and the result is, according to the degree of heat employed, either *malleable* iron or a *non-malleable* iron. The process of making malleable iron in this way is called, generally, the direct process—in German, *Rennarbeit.* It produces the iron in a solid state with a fluid cinder. By this process our ancestors made all their iron, and it has been revived in various ways in modern times up to the process of Mr. Blair, so far as I know, always without commercial success. The

product of this process we call *Renneisen* (with the subdivisions *Renneisen* and *Rennstahl*), for which I would propose in English the name of *run iron* (French, *fer de loup*). As the heat increases you get an iron which is too rich in carbon to be malleable; this is called generally *pig or cast iron* (*Roh, or Gusseisen*), French, *fonte or fer fondu.* It is made in the blast-furnace, both gangue and iron being separated in a fluid state. There could be a third process, namely, to leave the rock in the solid state and melt the iron; but this is not yet practiced. The largest amount of iron is used in the malleable state, and, therefore, most of the pig iron must be converted again into that state. This is done by processes whichtake out a certain amount of carbon, and, besides, some other matters, principally silicon. These processes, of which the three most used in practice are the charcoal-finery, the puddling, and the Bessemer processes, are called in German, *Frischprocesse;* English, *fining;* and for the product I propose, *Frischeisen*, English, *fined iron* (subdivisions may be: charcoal-hearth iron and steel, puddled iron and steel, Bessemer iron and steel), French, *fer affiné.*

It often occurs in these processes, that by design or by accident the carbon is entirely taken out, and the iron may even become partially oxidized. In these cases it is necessary to add to the iron substances which take out the oxygen, and also, in most cases, add carbon. We have different processes, as, for instance, the cementing process, which puts carbon into iron when only heated, but not melted. But the way most used at present is to add pig iron (often spiegeleisen), or a substance of allied composition containing manganese or silicon, with the fined iron, to get rid of the superfluous oxygen and to increase the amount of carbon. In these cases we obtain a molten product. Therefore we call it in German, *Flusseisen* (with the subdivisions of *Flusseisen* and *Flussstahl*), and I propose in English the name of *flow iron* or *ingot iron* (French, perhaps, *Fer coulé* or *fer de l'ingot*). You can make by one of these processes at will, an iron of any degree of carbon. So, for instance, Parry made cast iron again, and fined it by the Bessemer process: or you can take run iron and melt it with pig iron. That makes no difference in the nomenclature. I should be glad if this occasion should lead to a definite international nomenclature, which, in my opinion, is so very necessary.

F. Firmstone.—I agree decidedly with Doctor Wedding that hardening is the essential property of steel, no matter how made. I

think that the terms proposed for the different processes by which it is possible to make iron are good, and may finally come into English technical literature, but the past has left us one or two unfortunate words which closely resemble some of those proposed for the new nomenclature.

If my memory serves me, Percy laments his inability to use the words "fining" and "finery processes," for those methods which produce what Dr. Wedding proposes to call "fine iron" or "fine steel," because in England they call *re*-fining the process, preliminary to the conversion of cast iron into malleable, which consists in blowing on melted gray iron to change it into white before its use in the charcoal forge or puddling furnace.

His objection was to the use of the term *refining* for the preliminary process, and of *fining* for the finishing process, and perhaps is hypercritical, but as far as it goes it is an objection to Dr. Wedding's proposed word. In common conversation, too, and perhaps also in books (but I am not so sure of that), the product of the refinery is called "fine metal."

Again, the term "run iron," in England, would cause no confusion, but in America we very frequently, and perhaps generally, at least in Central Pennsylvania, call the refinery (the fire in which gray pig iron is changed into white) the "run-out" fire, but neither this, nor the objection above, to the term "fine iron" is of much moment in itself, and is of very little moment in the future, because the refining process has now almost entirely gone out of use.

PROF. EGLESTON.—I think Dr. Wedding's paper is a step in the right direction. When we come to discuss processes, and the products of these processes, it is necessary that we should use terms which will be understood, not only in our own, but in all other languages. To use words which are not understood, and which are difficult of translation, is an impediment to progress. Dr. Wedding's suggestion of an international committee to settle what terms are to be used, it strikes me, hits the keynote of the solution of the whole subject. Nearly all the great iron-producing nations are represented here, and since it seems very desirable that we should use either a common language or words susceptible of being translated, when we speak of processes and products, I think it would be possible to have a committee appointed by the Institute for the purpose of discussing this question in detail, in the hope of setting at rest the confusion which has arisen from the use of words which convey a definite meaning to one author, or, perhaps to one country, but not to another.

We used to know what the words steel and iron meant. The ideas which they conveyed were for a very long time fixed. The progress of iron and steel industry has within a few years made the words almost unintelligible. I see no reason at all why we should not use other words, and if an international committee could agree as to what these words should be, we should not only be able to get at what would express our meaning, but possibly a simpler scientific classification of our iron and steel processes. Dr. Wedding's classification, with its accompanying diagram, seems to me to be the most philosophical which has yet been presented, and, therefore, a very good basis for the attempt to solve the question.

No one knows better than myself the difficulty of getting correct words to express the ideas of phases of processes. I think there is some objection to some of the terms which have been proposed. From the run-out fire we have been in the habit of calling the product, not fine, but *fined* metal, because the process is a process of fining. The metal which comes out is not fine, or pure metal, fit for commercial purposes, but it is fined metal; that is, metal which has undergone a process of oxidation, which has been stopped at a certain point. Refined iron is altogether another thing. It is an iron which has gone through the process of refining, and is a merchantable product, as is also fine iron. We, therefore, have the words fine, fined, and refined, all of them expressing different ideas, and yet so nearly alike that it requires a considerable effort of the voice to make the terms distinctly understood. If these words were written, there would be no difficulty whatever, but it seems possible to substitute others which would be just as precise and not so difficult to distinguish. There are many other terms that are even more objectionable. It is, however, impossible to go into this matter in detail here. It seems to me that the only solution is that of an international committee to discuss and agree upon the words. We have taken fifteen years to get into this disagreeable confusion, and it will take some time to get out. If the committee were appointed now, and the representative of each nation should use the proper means to bring the subject before his own countrymen, we might, in two or three years, arrive at a solution, for it would take that time at least, since after the matter had been agreed upon in committee it would have to be accepted by the different nations interested, and the world at large. It seems to me perfectly feasible either to fix upon words which can be translated from one language into another; or, perhaps, the same, or some of the same words, might be admitted in

all languages without translation. When we have accomplished this, I think we shall have solved a very important question, and that we shall also ascertain that our present difficulties, which are those of words, are more apparent than real.

MR. HOLLEY.—I quite agree with Dr. Egleston; it seems to me that this discussion in which some of us have taken part, about "what is steel," and "what steel is," and what steel is not, has been more amusing than profitable, except that it has been profitable in this respect—it has shown us how incomplete the present nomenclature is. It seems to me that for the very first time in this Institute, and the first time anywhere, so far as I am aware, Dr. Wedding has proposed a nomenclature which will approximately suit the conditions of the case. I do not quite agree with him in regard to the particular terms, but as to the theory, perfectly. The other day I had the pleasure of quite a long discussion on the subject with Prof. Akerman, Prof. Prime, and Mr. Fritz. We concluded to agitate the question of proposing a nomenclature something like that suggested by Dr. Wedding.

The idea was to call all malleable compounds of iron cast from fluid state, whatever their amounts of carbon, and whatever their properties of taking temper might be, "ingot metal." All forms of wrought iron were to be called "pile metal," and catalan products, and the like, were to be called "bloom metal." I think we might, without waiting two or three years for Prof. Egleston's committee, settle the nomenclature now.

PROF. EGLESTON.—It might be settled sufficiently now, but it would take two or three years to have it introduced.

MR. HOLLEY.—It seems to me so sensible that the public would accept it at once. What does Dr. Wedding think of this nomenclature—"bloom metal," "pile metal," and "ingot metal?"

DR. WEDDING.—About bloom metal I quite agree, because there is no reason why that name should not be used, instead of run metal, as I proposed. About the name *ingot metal* we agree quite. But I think the name *pile metal* should not be used, because the puddled ball is not a piled metal, but is a product of one of a series of processes which belong to the same group of metallurgical operations, as charcoal-hearth fining. It is true that most of the bars, coming forth from the puddling process will be piled, but the process of piling has nothing to do with the nature of this iron. Indeed, Mr. Borsig, at Berlin, makes plates of large puddled balls, which are not piled at all, but worked as a whole. Out of the charcoal

finery fire, again, we get a ball of iron, which though generally not piled, is sometimes piled, for instance, for heads of rails.

Again, Bessemer iron is very seldom piled; but if it is, it keeps the same nature, and you can hardly call it pile iron in the sense proposed by Mr. Holley. Therefore I wished to have another expression, giving the nature of the iron, which would be correct for puddled iron and steel, fined iron and steel, etc.; and perhaps you will find, better than I, one in the English language—perhaps pile iron, which means not that the iron *is* already piled, but that it *can* be piled and welded.

Mr. Holley.—The term "pile" was intended to be opposed to the term "cast." We have got to have some term which expresses a heterogeneous, as distinguished from a homogeneous metal. The term pile is not exactly right, although when a portion of the puddled ball has been folded on another portion, it is piled, to a certain extent, just as puddled balls are piled upon one another.

A Member.—Would it not be as well to use the term welded iron instead of piled?

Prof. Frazier.—Why not use homogeneous and heterogeneous instead of "piled" or "ingot;" in other words, I object to any method of classification based on the process of manufacture, because such a classification must be temporary and changed as processes are varied. Any method of classification to be permanent must, I think, be based upon the characteristics of the metal, or on its average characteristics.

Dr. Wedding.—Allow me to say now, after this discussion, that I should like the term welded iron better than piled iron. I should ask if it is not possible in the English language to say "weld iron;" I mean iron which *can* be or *may* be heated and welded.

Mr. Coxe.—Would not welding iron be better?

SOME POINTS IN THE TREATMENT OF LEAD ORES IN MISSOURI.

BY PROF. C. P. WILLIAMS, PH.D., ROLLA, MISSOURI.

The lead-bearing area of Missouri has been subdivided, geographically, into the Southeastern, the Central, and the Southwestern

regions. The first includes the counties of Franklin, Jefferson, Washington, St. François, Madison, St. Genevieve; and, of subordinate importance, in so far as activity of operations is concerned, Crawford and Bollinger. In this region the third magnesian limestone—a member of the calciferous epoch—is the productive rock. The principal points of development in the Central region are found in Miller, Cole, Morgan, and Moniteau Counties, to which may be added Saline, Cooper, Pettis, Benton, St. Clair, Hickory, Camden, Osage, and Maries, as well-established for lead deposits, but in which the mining operations have not been so extended. With the exception of parts of Moniteau, Saline, and Cooper, the geological horizon of the ores is either identical with that of the Southwestern region, or the ores occur in a more recent member of the same series—the second magnesian limestone.

In the exceptional instances named, the ores are found in the Archimedes limestone, of the Subcarboniferous epoch, and are, therefore, allied, geologically, with the deposits of the Southwestern region, in which the productive rock is of that age. The Southwestern region includes Jasper, Newton, Greene, Dade, McDonald, Barry, Stone, and Christian Counties; the first two being pre-eminent in the number of the lead-smelting establishments.

The modes of occurrence of the lead minerals in these regions have been described at such lengths in the various geological reports of the State, more especially in that of Broadhead, that little need be said on this point in this connection. This ore is almost entirely galenite; the so-called carbonate ores being generally mixtures of galenite with more or less cerussite, giving rise to what is locally called "ash mineral," when the former predominates, or "wool mineral," when the latter is in excess. At times compact earthy masses of carbonate, of a white, yellow, or reddish color, are found, but rarely in sufficient amounts to modify the furnace treatment to any notable extent.

On analysis of a sample of crushed carbonate ore, or "wool mineral," from the Granby Works, Newton County, I obtained the following results:

	Per cent.		Per cent.
Lead carbonate,	84.077	Cupric oxide,	.058
Lead sulphide,	6 239	Ferric oxide,	.434
Zinc oxide,	2 091	Silicious matters,	2 490
Antimony oxide,	.109		

Lime, magnesia, carbonic acid in gangue not estimated.

The character of the galenite from the several regions is indicated

in the annexed table of results, obtained in estimating the foreign metals (excluding the always small amounts of silver), in well-selected specimens of nearly pure galena ore, or of the crushed and washed ores treated at several of the smelting establishments:

SOUTHWESTERN REGION.

	Antimony. Per cent.	Copper. Per cent.	Iron Per cent.	Zinc. Per cent.	Other Foreign Metals. Per cent.
I.	trace.	trace.	.05867	.06782	
II.	.07429	.00478	.02169	.00938	Nickel, 0660
III.	.00551	.00239	.08602	1 35554	
IV.	.02764	.01677	.03220	1 76558	
V.	trace.	none.	.12040	.14679	

CENTRAL REGION.

	Antimony. Per cent.	Copper. Per cent.	Iron Per cent.	Zinc. Per cent.	Other Foreign Metals. Per cent.
VI.	.04178	trace.	.02310	.00804	Nickel, .09755
VII.	.00317	.00798	.07050	.00268	
VIII.	.00475	.01197	.00980	.00602	
IX.	.04754	none.	.02940	trace.	
X.	trace.	none.	.02240	.00372	
XI.	trace.	none.	.78400	.00019	

SOUTHEASTERN REGION.

	Antimony Per cent.	Copper. Per cent.	Iron. Per cent	Zinc. Per cent.	Other Foreign Metals. Per cent.
XII.	.05069	4.6557	8.1304	.3255	Co. trace.
XIII.	trace.	none.	2 5290	.0400	Ni. .214 Co. trace.
XIV.	trace.	.0800	1.9530	none.	Ni .168 Co. .357
XV.	trace.	.1030	1.4350	trace.	Ni. 213 Co. .042
XVI.	.03100	.0410	.0110	.0540	As .026
XVII.	none.	13 3190	13 5170	.0200	Ni. .233 Co. trace.

I. Washed galenite from jig at Granby, Newton County; II. Block mineral, Joplin, Jasper County; III. "Number 1," block mineral, Granby; IV. Holman's Diggings, Newton County.

Chauvenet's analysis of ore from these diggings shows (*Broadhead's Report*, p. 388)—Lead, 84.06; zinc, 0.94; iron, 0.16; antimony, none; silver, .0039 (= $1\frac{1}{4}$ oz. per ton of 2000 lbs. ore); silicious matters, 0.61 per cent. The lead corresponds to 97.05 per cent. galenite, and the zinc to 1.41 per cent. sphalerite.

V. Birch Diggings, Joplin, Jasper County; VI. Block mineral of remarkable purity, selected at the Eagle Furnace, Sec. 23, T. 43,

R. 14 W., Cole County; VII. Ore used at Murphy & McClurg's Furnace; VIII. Pioneer Furnace ore; IX. Star Furnace ore; X. Buffalo Furnace; XI. Ore used at O'Brien's Scotch hearth; XII. St. Joe Mines, with visible admixture of chalcopyrite, pyrite, and blende—contained 31.032 per cent. lead, 5.826 silica, besides calcite, and showed distinct traces of nickel, but the amount was not estimated; XIII. From Bluff Diggings, Mine La Motte; XIV and XV. Washed ore from Bluff Diggings, Mine La Motte, sluge and headings respectively; XVI. Perry Furnace, near Potosi, Washington County; XVII. From "Seed-tick Diggings," Mine La Motte tract, analyzed under my direction by W. C. Minger; sample showed chalcopyrite.

The chief associates of the ore are calamine, smithsonite, and sphalerite predominating in all the localities, and barite in the deposits of the Southeastern and Central, but not noticed in the Southwestern region. The following species are also found, but less abundantly than those named: dolomite at nearly all the localities; azurite and malachite in some of the deposits of Morgan, Miller, and Cooper Counties; pyrite and chalcopyrite, the first in nearly all the ores, and the latter in small quantities, but most abundant in the Southeastern region. Besides these there are found, silica, free, either as quartz (rare), sand, quartzite or chert (quite common), or combined silica, chiefly as clay, limonite, and, in the Southwestern region, especially around Joplin and Oronogo, Jasper County, bitumen.

The preponderance of such gangues as calcite and barite, and the absence of notable amounts of foreign metals divests the treatment of the Missouri ores of any complexity either in the mechanical preparation or in the furnace operations. The method of extraction employed is always that of the air reaction, carried on either in the reverberatory or on the American modification of the Scotch hearth. In one instance only is the cupola process practiced, and that is in the treatment of the nickeliferous ores and residues from Mine La Motte, with a view to the production of nickel matte.

The distribution and number of the furnaces in active operation throughout the State at the present writing are as follows:

	Reverberatories.	Hearths.
Southeastern region,	11	7
Central "	19	1
Southwestern "	24	15
Total,	54	23

In addition to these may be named three slag furnaces for the treatment of residues in the Southwestern, and four in addition to the Mine La Motte cupolas in the Southeastern region.

The reverberatories in use in the State are either of the Flintshire form, or on a plan of a modified Carinthian furnace. Two Flintshire furnaces have been operated at the Granby Works in Newton County, and one at the Frumet Mines in Jefferson County, these three completing the list of that form of furnace in use throughout the State. Since both forms are worked at Granby this establishment is selected for more especial notice.

TREATMENT IN THE FLINTSHIRE FURNACE AT GRANBY.

The hearth is 10 feet by 8.5 feet, and is made of slag from the furnace, thoroughly agglomerated by strong heating and beating, and shaped into the ordinary sump near the middle door on the front or work side of the furnace. The fire-bridge is one foot in height above the sole at that point. The fire-box is 3 feet by 8 feet in section, and three feet in depth measured from the top of the fire-bridge.

As several grades of ore are run through these furnaces, and as no valuation is made by assay, the amount of charge is variable. In general, for No. 1 block mineral (first grade galenite assaying from 78–81 per cent. usually) it is 1500 lbs., worked off in twelve hours; for No. 1 wash mineral (= 70–74 per cent.) 1500 lbs. are worked off in fourteen hours; for so-called carbonate ores, 1000 lbs., worked off in six hours; and for "chats" (*i. e.*, galena or chert or dolomite which is burnt at a low red heat to make the rock friable and easily broken by hand for sorting or rough washing) 1000 lbs., worked in ten hours.

The roasting period never exceeds two hours' duration for the first grade galena ores, and the tapping is done at the end of ten and a half hours after the charging. Before tapping, the mass is thickened by the addition of wood ashes and filled up around the sides of the hearth in order that the lead may better drain into the sump. After tapping, the fire is again urged, and more lead is drained, which is tapped off as before, after which the residue or "gray slag" is drawn, the sole repaired, if necessary, and a fresh charge introduced.

The labor required for each furnace is that of two men, working twelve-hour shifts in winter, and eight hours in summer. Six cords of wood are consumed per furnace per twenty-four hours, or 42 cords per week, representing the treatment of 35,000 lbs. of average mineral, yielding about 66 per cent. in the furnace.

The "gray slag" is not homogeneous, and there is, therefore, difficulty in reaching its average composition by chemical analysis. A lot representing the average of the residue from the run of a block mineral charge yielded 1.02 per cent. of shot or inclosed metallic lead, while the remainder gave the following result:

	Per cent.		Per cent.
Silica,	12 557	Lead sulphate,*	2.509
Lime,	642	Lead sulphide,	22.084
Magnesia,	trace.	Lead oxide (by difference),	55.939
Ferric oxide (Fe_2O_3),	3 220		
Alumina,	.642		100 00
Antimony oxide (Sb_2O_4),	.170	Total metallic lead,	72.766
Zinc oxide,	2.264		

Unfortunately, I have not been able to arrive at any knowledge of the amount of residue produced in a run of ore, but the large amounts of sulphide and oxide existing in the sample make it evident that in so far as the yield of lead is concerned, a supplementary or setting-up stage might have been added to advantage.

ORDINARY REVERBERATORY PROCESS.

The reverberatories in general use in Missouri have the sole oblong and sloping downwards, in the direction of its greatest length from the charging end of the furnace toward the pot or discharging end, usually at the rate of 2 inches per foot (9.5° angle). The corners at the lower end of the hearth are cut off obliquely; the fire-box forms an L attachment near the pot end of the hearth, its direction of greatest length being at right angles to that of the latter. Hence the charge is worked down gradually from the cooler to the hotter part of the furnace, that near the fire-bridge, which is but a short distance from the work door. The hearth of the Granby reverberatories is 9 by 3 feet; the fire-box is 6 feet by 2 feet 6 inches. The sole is a cast-iron plate with about six inches of residue melted upon it.

The usual charge is 1500 lbs. No. 1 mineral, worked off in twelve hours, requiring one smelter and one helper, and consuming 1.5 cords of wood. The roasting period is from one to one and a half hours' duration, during which time the charge is frequently stirred in order that all parts may be worked at times down toward the

* Determined directly by solution in sodium hyposulphite. The same method was used with all the residues and slags.

hottest part of the furnace. At the end of the roasting period the fire is pushed, but not sufficient to cause fusion, the latter being prevented, when necessary, by the addition of ashes. At the end of from nine to eleven hours the lead ceases flowing, and the charge is deemed elaborated. The residues are then withdrawn, and the somewhat cooled furnace is ready for another charge.

A sample of residue from a charge of No. 1 mineral contained 3.52 per cent. of mechanically inclosed or shot lead, after the separation of which the remainder gave the following result on analysis:

	Per cent		Per cent.
Silica,	21 396	Lead sulphide,	20 929
Lime,	4.650	Lead sulphate,	2 349
Magnesia,	3.948	Lead oxide,	34.914
Ferric oxide,	3 680		
Alumina,	.152		99.063
Zinc oxide,	7.146		

The amount of metallic lead is 54.820, including the mechanically inclosed grains.

These residues, together with those from the Flintshire, the Scotch hearths, and those purchased from other furnaces at Joplin, are passed for treatment in a "slag eye," or furnace generally similar in construction to the English slag furnace. The products are slag and slag lead. The former shows the following composition:

	Per cent		Per cent
Silica,	37 648	Zinc oxide,	14 221
Lime,	4 005	Antimony oxide,	trace.
Magnesia,	1.754	Ferrous sulphide,	1.927
Alumina,	3 268	Lead sulphate,	.359
Ferrous oxide,	2 258		
Lead oxide,	33.778		99.218

The oxygen of the acid to that of the bases (after deducting the ferrous sulphide and lead sulphate regarded as mechanically mixed) is as 20.71 to 10.17. No flux is added, evidence of which is seen in the large amount of lead oxide. Coke is used for fuel. A similar process of residue or slag smelting is practiced at one other establishment in the Southwestern region, at Joplin, and yields a slag composed as below:

	Per cent.		Per cent.
Silica,	24.527	Lead oxide,	47 619
Lime,	6.135	Lead sulphate,	2.765
Magnesia,	1 055	Lead sulphide,	1.165
Alumina,	.361	Ferrous sulphide,	5.189
Antimony oxide,	trace.		
Zinc oxide,	10.335		99.146

The following table will exhibit the work of such of the other reverberatories concerning which I have been able to collect sufficient details:

Name.	Areas. Hearth, sq. feet.	Areas. Grate, sq. feet.	Charge, lbs.	Time, hours.	Wood, per charge, cords	Fuel per 2000 lb ore.	Labor. Days per 2000 lb. ore
1. Lone Elm, Jasper Co , .	. .	. .	1500	8	0 80	1.20	2 62
2. Dade County M &S Co.,	. .	. .	1200	8	0.40	0.66	3 32
3. Pioneer, Cole County, .	34	9 5	1800	12	0.75	0 84	3 32
4. Eagle, "	35.3	10	1500	12	0.63	0 84	4 00
5. Gum Spring, Morgan Co.	. .	. .	1500	24	0 25	1 66	8.00
6. Buffalo, "	. .	. .	1500	12	. .	. .	4 00
7. Star, "	28.5	14	1500	8	. .	. .	2 62
8. Wyan Spring, "	52 5	12	1800	24	1 13	1 26	6 66
9 Bonds. "	32	18	1500	24	0.75	1 00	8 00
10 Linn Creek, "	32	9	. .	. .	. .	. .	. .
11. St. Joe, St François Co.,	42	20	2000	8	0 75	0.75	4 00
12. Granby, Newton Co., .	27	15	1500	12	1.50	2 00	4 00
Mean, ...						1.13	4.58

From the above it will be seen that the average consumption of fuel is 1.13 cords of wood per ton of ore put in treatment, and that the mean amount of labor required is 4.58 days (of eight hours' shift) for the same weight. The Flintshire form of furnace at Granby requires 2.4 cords of wood, and four days' labor per ton of ore treated. For the Flintshire furnaces in England, I have calculated that the fuel and labor are, respectively, 1.24 cord (1 lb. wood in the reverberatory = 0.35 coal), and 1.28 day, while for the Bleiberg furnace, the consumption of fuel is at the rate of 1 cord per ton, and the amount of labor 4 days.

It would appear that the ordinarily employed air or reverberatory furnaces of Missouri, compared with their closest European prototypes, work with more regard to economy in fuel than in labor, and are, in this respect, scarcely in accord with the economic conditions of their localities. It is by no means certain that such effect was designed, but that it is rather a result of the decreased size of furnaces, and of a consequent greater relative weight of charge, with less manipulation of the charge on the sole.

The Flintshire furnace seems to be some improvement, though when compared with the English model it will be seen to be deficient in the proportion of its parts, and still extravagant in both labor and fuel. All the modifications have done little towards making

the system anything more than a rapid running out of the lead, produced—*First*, by a short roasting period, or that most expensive in manipulation; *secondly*, by a slow combustion, relatively to the weight of the charge on the sole, and consequently a moderately heated hearth; and, *thirdly*, by not pressing the residues.

The wastage of lead must be greatly increased, through greater volatilization and by increased weight of residue or slag and by a higher tenure of lead in the latter, but how far the system prejudices the yield of lead from the ore is difficult to ascertain, when operations are not controlled by laboratory work. It is known that a very large proportion of the ores of the Central region are of the character of No. 1 block mineral, and that much of that produced in the Southwest is of the same description; further, that the careful method of hand sorting and of washing is practiced on the Southeastern ores. From these considerations it may safely be assumed that the average assay yield of the ores run through the Missouri furnaces is not less than 78 per cent. lead. The furnace yield, from the results of nine reverberatories, I find to be an average of 61.5 per cent. metal, showing a waste in residue, and by volatilization, of 16 per cent. of the metallic contents of the ore, against 7.7 per cent. in the English and the Bleiberg furnaces.

The commercial effect of this wastage may be counterbalanced to some extent by the fact that the ores are abundant and of high grade, and that the lead in this manner would doubtless be of greater purity and softer than that mixed with the press lead, but it would appear that even with these offsets the interests of the furnace-owners would be better served by a lengthening of the time of treatment. For further illustration of the ordinary reverberatory process, I may select from among the list of furnaces two representing respectively the Central and the Southeastern regions.

Bond's Furnace (No. 9 of the table) is among the lowest in its rate of fuel consumption, and has therefore, the highest rate of labor, as a consequence of the small weight of ore passed through in the twenty-four hours. The charge produces, usually, twelve pigs of ninety pounds each, or 1080 pounds of metal, equivalent to 72 per cent. of the ore treated. The grate and hearth areas are to each other as one to four; the consumption of fuel is about 13.5 lbs. wood* per square foot of grate per hour. The furnace is operated from four to six

* One cord wood (128 cubic feet) = 86 solid cubic feet; a cubic foot of average wood in use at the furnaces weighs 40 lbs.; a cord = 3440 lbs.

months in the year; the fire-brick (of St. Louis manufacture) last two such campaigns. The residues contain:

	Per cent.		Per cent.
SiO_2,	20.211	ZnO,	0.417
CaO,	7.791	PbS,	26.152
MgO,	1.641	$PbSO_4$,	1.932
Fe_2O_3,	4 459	PbO (by difference),	36.708
Al_2O_3,	0.557		
Sb_2O_4,	0.132		100.000

The St. Joe Mines (in St. François County) have eight reverberatories of the largest size in use in the State. The areas of the hearth and grate are as 2.6 to 1; the charge is two thousand pounds run through in eight hours, consuming 0.75 cord of wood and requiring two days' labor.

The furnace yield ranges between 65 and 70 per cent., say 67.5. The fuel consumed is 16.1 lbs. per square foot of grate surface per hour.

The residues have the following composition:

	Per cent.		Per cent.
SiO_2,	26.252	Cu_2S,	0 981
CaO,	.9 908	NiS,	0.777
MgO,	3.704	PbS,	37 792
Fe_2O_3,	11.533	$PbSO_4$,	3.455
Al_2O_3,	3 223	PbO (by difference),	2.316
AsO_3,	0.059		
Sb_2O_4,	trace.		100.000
ZnO,	trace.		

These residues are put aside for treatment in the future. As a general rule, finding its exceptions only in the cases indicated in the Southwestern and Southeastern regions, the so-called slags are discarded. When sold, as at Joplin, their market rate is $10.50 per miner's thousand (1120 lbs.), while ores rate, at the same time, at $23 per thousand, lead selling at seven cents per pound. There are no condensing-chambers or other apparatus looking to fume or dust collection at any of the reverberatories.

The character of the lead produced from the ores by the reverberatory methods will be sufficiently indicated by the results of analyses given below. These results were reached by following the method of Fresenius (*Zeitschr. Anal. Chem.*, VIII, 148; *Jahrsbericht für Chemie*, 1870, 906) for soft leads, with the exception of using 100 grams and estimating the silver by cupellation in a second portion,

also of 100 grams weight. In this manner my assistant, Mr. A. W. Hare, and myself have carried through analyses of all the brands of lead produced in Missouri, for the forthcoming Industrial Report A. of the Geological Survey, in which the metallurgy of lead will be examined in greater detail.

At the present I select only the brands produced at the furnaces more particularly described in this report:

	I.	II.	III.	IV.	V.
Arsenic, ...	0 01640	0 01122	nil	0 00183	0 00101
Antimony, . . .	0 00077	0 00077	0 00495	0.00675	0.04975
Silver, ...	0 00029	0.00080	0.00084	0 00405	0.00029
Copper, . . .	0.01210	0 05091	0.00556	0.06394	0 02965
Iron, ...	0 01711	0 01582	0 00411	0.00137	0.00718
Zinc, ...	0 00066	0.00090	0 00181	0 00082	0 00180
Nickel, . . .	trace.	0 00281	0 00195	trace Cd	0 00276
Lead by difference, .	99 95267	99 91677	99 98078	99 92124	99.90756
	100 0000	100 0000	100.0000	100 0000	100 0000

No. I. From Granby Flintshire furnace, sample represents 10 pigs of metal; II. Granby ordinary furnace, representing 16 pigs; III. Bond's Air Furnace, brand "Gravois;" IV. From the St. Joe reverberatories; V. Slag lead from furnace at Granby, refined by remelting in the Flintshire furnace with poling. The other leads are not refined beyond simple poling in the kettle before casting.

Hearth Treatment.—The modified hearth, with the water-back (or double-walled sides with circulation of water), and with three tuyeres, is that in most general use in the Southwestern region. At the Granby works there are six such, each treating 3000 lbs. of high grade ore, per eight hour shift, with two smelters and one helper, the latter serving two hearths with ore and coal. Two shifts per day are usually worked, for six days, equivalent to 216,000 lbs. mineral, yielding 181,200 lbs. or 70 per cent., consuming 660 bushels hardwood charcoal and 60 bushels of lime for so-called flux. At Lone Elm about the same amount of ore is put in treatment to each hearth, the yield being 66.6 per cent., and the fuel, 15 bushels of coal per 3000 lbs. of mineral. There are twenty-one such hearths in operation in the Southwestern region.

In the Central region there is but one hearth, which is of the older form, with single tuyere. It treats 6000 pounds mineral daily in three eight-hour shifts; the yield is sixty pigs of lead, weighing

67 lbs. each, or 4020 lbs., equivalent to 67 per cent. of the mineral treated.

The residue contains a small amount of shot lead (0.07 per cent.), and yields, after separation of this, the following:

	Per cent.		Per cent.
SiO_2 (with a little $BaSO_4$),	43.065	ZnO,	0 450
CaO,	5.226	PbS,	28 934
MgO,	1.345	$PbSO_4$,	0 432
Fe_2O_3,	3 021	PbO,	17.219
Al_2O_3,	trace.		
Sb_2O_4,	0.334		100.026

At the Perry Furnace, Washington County, a single tuyere hearth of the older style, three thousand pounds of ore are worked by the same set of smelters, for the production of 30 pigs of 70 lbs. each, giving a yield of 70 per cent., and consuming ten bushels of coal. The residues are crushed and washed, and passed to treatment in the same hearth.

At the Vallé Mines are two of the same description of hearths, each treating 3500 lbs. raw ore in eight hours, consuming four bushels of coal and about one-twentieth cord of wood, and producing 33 pigs of 75 lbs. each (for the Rozier brand), or 2475 lbs., or 30 pigs of eighty pounds each (of the Vallé brand), or 2400 lbs of metal. There is a difference in the character and preliminary preparation of the ore used for the two brands of lead. The residues are passed to a small cupola, in which 5000 lbs. are treated in twelve hours by the labor of two smelters and one helper, producing 18 pigs of 60 lbs. each, or 1080 pounds, or 21 per cent. The slag lead is branded "Phœnix."

At Mine La Motte, two of the improved hearths are in use, the duty of each being the treatment of 3200 lbs. of mineral in six hours. The yield is about 70 per cent. The amount of labor required per ton of mineral treated on the hearth averages 1.66 day, and the charcoal 5.2 bushels per ton of mineral in either form of hearth, the advantage of the improved form being chiefly in its greater durability. It is, however, a more costly form of apparatus. The consumption of fuel indicated does not include that required for the blowing apparatus, nor is the time of the engineer included in the labor. A four-ounce pressure is commonly used for the blast.

To further illustrate the character of the hearth residues I select here an analysis of that produced at Mine La Motte, made in my

laboratory by Mr. W. C. Minger. The empirical result is given (A), together with the rational result (B) calculated from the same:

A. EMPIRICAL COMPOSITION.		B. RATIONAL COMPOSITION.	
SiO_2,	17 465	SiO_2,	17.465
Al_2O_3,	4.349	Al_2O_3,	4.349
CaO,	10.309	CaO,	9.242
MgO,	3.413	MgO,	3.413
BaO,	0 469	$CaSO_4$,	2 580
Co,	0 438	$BaSO_4$,	0.714
Ni,	0 852	$PbSO_4$,	4.174
Zn,	0.327	CoS,	0.675
Fe,	4 114	NiS,	1.242
Pb,	45 977	ZnS,	0 488
S,	7.341	Fe_2O_3,	5.877
SO_3,	2.863	PbS,	48.758
O (by calculation),	2.049	PbO,	0,990
	99.966		99.967

The following are the characters of the leads produced at some of the hearths named:

	I.	II.	III.	IV.
Arsenic,	0.00583	0 00825	trace	0 00034
Antimony,	0.00803	0.00184	0.00214	0 00119
Silver,	0.00219	0.00615	0.00326	0.00345
Copper,	0.00585	0.03742	0.04165	0.01999
Iron,	0.00145	0.02497	0 00453	0 00248
Zinc,	0.00156	0.00118	0.00294	0 00164
Nickel,	trace	none	none	0 00095
Lead (by difference),	99.97509	99.92019	99.94548	99 96996
	100.00000	100.00000	100.00000	100.00000

I. Lead from Hopewell hearth; II. From Vallé hearth, Rozier brand; III. From same, Vallé brand; IV. Mine La Motte.

By comparison of the hearth and the reverberatory methods it will be seen that in the former the consumption of fuel and labor per ton of ore is less. On the other hand, the residues are not so clean, and the loss by volatilization is greater, and consequently the yield of lead is less in the hearth than in reverberatories. Further, the hearths are much more costly at the outset; besides, the accessory apparatus for the blast requires labor and fuel, which items, as before noted, have not been taken into account in the expenses given above. I am inclined, however, to the opinion that, other things being equal, the hearth lead will be purer than that run from the reverberatories.

The residue treatment at Mine La Motte is of interest in connection with the production of nickel. The residues from the hearths, mixed with roasted ores, which are notably nickel-bearing, are treated in a cupola of trapezoidal section, and with three tuyeres of 2⅝ inch nozzle, delivering a blast under a pressure of 10 ounces. The fuel is coke, and the flux hematite from the Iron Mountain region. The products are slag, first matte, and lead. The compositions of the slag and matte are shown by Minger's analysis to be as follows:

SLAG.

EMPIRICAL COMPOSITION.	Per cent.	RATIONAL COMPOSITION.	Per cent.
SiO_2,	53.435	SiO_2,	53.435
Al_2O_3,	6.219	Al_2O_3,	6.219
CaO,	15.056	CaO,	15.046
MgO,	8.653	MgO,	8.633
Co + Ni,	0.514	K_2O,	0.708
Zn,	0.291	FeO,	0.988
K_2O,	0 708	(Co + Ni) S,	0.793
Fe,	11 328	ZnS,	0 436
S,	3.441	Fe_2S,	13.576
O (by calculation),	0 219		99 834
	99.864		

MATTE.

EMPIRICAL COMPOSITION.	Per cent	RATIONAL COMPOSITION.	Per cent.
SiO_2,	20.827	SiO_2,	20 827
Al_2O_3,	8 434	Al_2O_3,	8.434
CaO,	7.867	CaO,	7.867
MgO,	3.442	MgO,	3.442
Cu,	0.192	Cu_2S,	0.241
Zn,	0.139	ZnS,	0.208
Co,	1.195	CoS,	1.843
Ni,	2.486	NiS,	3.828
Pb,	5.762	PbS,	6.659
Fe,	36.345	Fe_2S,	33,359
S,	10 418	FeO,	13.370
O (by calculation),	2 971		100.078
	100.078		

The result of the analysis of the lead is as follows:

	Per cent.		Per cent
Arsenic,	0.00125	Zinc,	0.00458
Antimony,	0.00119	Nickel,	0.00519
Silver,	0.00564	Lead (by difference),	99 89337
Copper,	0.08544		100.00000
Iron,	0.00334		

The slags are thrown aside. After deducting the sulphides (regarded as mechanically mixed) they show an oxygen ratio of 4.5: 10 (nearly).

The matte is roasted and the product passed to second treatment in the same furnace, yielding a concentrated matte and slag. The roasted and concentrated mattes have been analyzed by Minger, under my direction, with the annexed results:

ROASTED MATTE.

EMPIRICAL COMPOSITION.	Per cent	RATIONAL COMPOSITION.	Per cent
SiO_2,	7 804	$NiSO_4$,	0.186
Al_2O_3,	2.221	$CaSO_4$,	5 442
CaO,	2 241	$FeSO_4$,	1.338
Ni,	3.721	SiO_2,	7.804
Co,	2.203	Al_2O_3,	2 221
Cu,	1.523	NiS,	5.631
Fe,	56 591	CoS,	3.398
SO_3 (soluble in water),	3 979	Cu_2S,	1 908
O (by difference),	19 717	Fe_2S,	31.041
		Fe_4S,	1.154
	100.000	Fe_2O_3,	39 877
			100 000

CONCENTRATED MATTE.

EMPIRICAL COMPOSITION.	Per cent.	RATIONAL COMPOSITION.	Per cent.
SiO_2,	1.436	SiO_2,	1 436
Al_2O_3,	2.659	CaO,	4.653
CaO,	4 653	Al_2O_3,	2 659
MgO,	0 776	MgO,	0.776
Ni,	5 685	NiS,	8.769
Co,	2.005	CoS,	3 092
Cu,	0.608	Cu_2S,	0.762
Zn,	0 282	ZnS,	0.421
Fe,	63.819	Fe_4S,	36 976
S,	16.317	Fe_2S,	32.536
O (by difference),	1.760	FeO,	7.920
	100.000		100.000

That a large number of the leads produced by the Missouri furnaces, more especially by those in the Central and Southwestern regions, are excellently well adapted for purposes of corrosion into white lead, has long been known by Western manufacturers. The corroders of the Eastern cities have, of late, realized the value of

the furnaces of these regions as a source of supply of lead, and during the past year a large amount of Missouri soft metal has found its way eastward, giving satisfactory results in respect both to the degree of corrodibility and the color, and other characters of the resulting white lead. I have compared, side by side, a corrosion of Southwestern Missouri lead with one of Tarnowitz, both by the same manufacture, and while the trained eye could perhaps distinguish under such circumstances that the creamy tint of the white lead from the Tarnowitz was wanting in that from the Missouri lead, yet the difference was not sufficient to warrant any choice for practical use, beyond such a one as might be founded in prejudice.

Such slight differences in properties of the white lead, as well as variations in the amounts of corrosion, I am satisfied, from a somewhat extended experience, are chargeable, not so much to differences in quality of lead, as to variations in the temperature and other internal conditions of the stack in which the leads are corroded, and these conditions are too little understood to be under the control of the manufacturer, in spite of the long time during which the so-called Dutch method has been in use. As a matter of some interest in this connection, I produce here some analyses which I have already published,* which bear on this subject, and have placed side by side Hampe's results in a similar direction with some of the white leads from European leads:

	I.	II.	III.	IV.	V.	VI.
Arsenic, .	0.00019	nil.	nil.	nil.	nil.	0 00217
Bismuth, .	nil.	nil.	0.004841	0 006276	trace.	nil.
Copper, .	0.00479	0.00926	0.001708	0 000431	0.000556	0.01381
Antimony,	0.00198	0.00076	0 001236	0.000903	0 000444	0 00158
Silver, . .	1.00045	0 00034	0 000500	0 000500	0.000130	0.00050
Iron, . .	0.00220	0.00085	0.002100	0 000728	0 000903	0 00315
Zinc, . .	0 00142	0.00025	0.000305	0.000128	0.000257	0.00770
Nickel, .	0.00047	0.00007	trace.	trace.	nil.	0.00055
Cadmium,	nil.	nil.	nil.	nil.	0.000360	nil.

I, is pig lead used in the production of II; II, unwashed white lead from preceding; III, ordinary Hartz white lead (Hampe); IV, white lead from Lautenthal lead (ib.); V, white lead from Silesian lead (ib.); VI, residual blue lead or kernel from II.

* Report of the University, State of Missouri, year ending June 14th, 1875, page 208 et seq.

PHILADELPHIA MEETING,

OCTOBER, 1876.

THOUGHTS ON THE THERMIC CURVES OF BLAST FURNACES.

BY H. M. HOWE, A.M., E.M., BOSTON, MASS.

I WISH to present to you a few thoughts on some of the phenomena and laws of iron smelting. Owing to the great complexity of the subject, to the great variety of points to be taken into consideration, many of which are very poorly understood, and to the meagreness and even conflictoriness of our information with regard to some of the most important laws which govern the subject, the fruits of such thoughts as I venture to offer you must be received as speculations, not as facts. Nevertheless, in discussing old phenomena from new standpoints, thus furnishing a metallurgical parallax, if I may say so, these theoretical speculations may have their value in helping to a clearer comprehension of the phenomena and laws we now know, and in suggesting new lines of inquiry.

While an increase of height in blast furnaces is not always followed by increase in their power of production, experience proves that it tends to increase it; for while we have many cases of short furnaces producing more iron than longer ones, yet enormous productions, such as those of the Lucy and Isabella furnaces of Pittsburgh, and of the furnaces of Esch sur l'Alzette, in Luxembourg, have never been reached in short furnaces. We may safely infer that height is an element essential to great production, though of course not the only essential element, and that, in the case of high furnaces which are not capable of great production, some other essential element is wanting. Moreover, experience teaches that within limits increase of height tends to increase the producing power in a still higher ratio. Thus, in the Esch furnace, which is 19.8 meters (65 feet) high, 393 tonnes (or 387 gross tons) of 31½ per cent. ore

have been smelted in twenty-four hours, with coke containing 18 per cent. of ash. Now, I doubt very much whether a furnace half as high (or 9.77 meters = $32\frac{1}{2}$ feet high), no matter how broad it be, could, under any circumstances whatever, smelt 98.5 tonnes (or 97 gross tons) of such ore in a day, or one-fourth as much as the Esch furnace.

Without discussing the other elements which are essential to great production, and without even asserting in what cases increase of

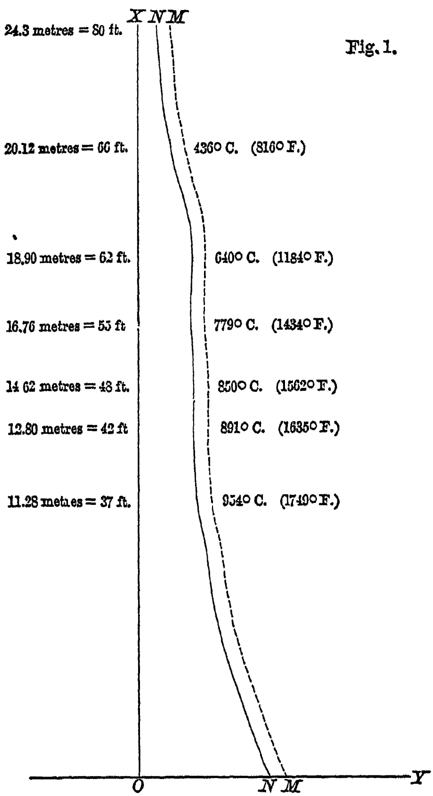


Fig. 1.

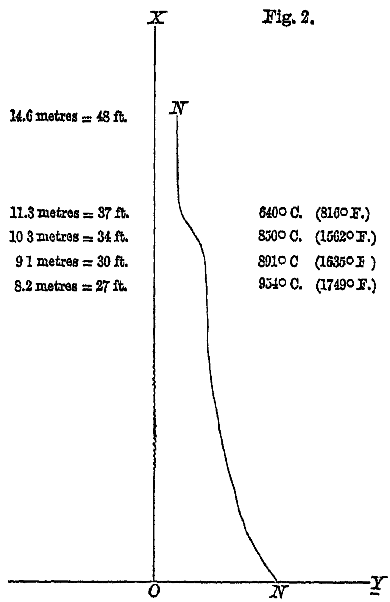


Fig. 2.

height will increase production, I propose to examine the element of height alone, simply trying to explain why, when all other circumstances are favorable, a slight increase of height may produce a much more than proportionate increase of productive power.

The thermic curves (or curves showing the relation between the temperatures of different points in the furnace and the height of those points above the furnace hearth) of the Clarence furnace, as given by

Bell,* I believe throw some light on this subject, and show us one, at least, of the reasons why the maximum production of very tall furnaces exceeds the maximum output of short ones, in a much greater ratio than that of the length of the tall ones to that of the short ones. (In these curves, Figs. 1 and 2, *N N·N N*, the ordinates are proportional to the heights of the different points in the furnace above the hearth, the abscissæ to the temperatures which Bell found at these points. The full line, *N N*, in Fig. 1 is the curve determined by Bell, the broken line, *M M*, being an imaginary curve of temperature to which I shall refer later.)

The shape of these curves is such as to lead us to infer that, if either furnace be so lengthened as to lower the temperature at which the gases escape, its upper and cooler zones will be lengthened by almost the whole amount of the total increase of heat of the furnace, while the lower and hotter zones will be hardly lengthened at all. This inference is strengthened by the fact that these upper zones in the 24 m. furnace exceed in length the corresponding zones in the 14 m. furnace in a much higher ratio than that of the total length of the former furnace to that of the latter, while the length of the hot zones is nearly the same in both furnaces. After dwelling on this point I shall try to show that the productive power of a furnace is limited by the length of cool zones, and that it is probably nearly independent of the length of hot zones.

I.

Taking, first, the case of the 24 m. furnace, let us assume—

(1.) That the gases escape at a temperature of 400° C. (752° F.).

(2.) That they weigh 6.6 tonnes per tonne of iron (or 130 cwt. per ton of iron).

(3.) That their specific heat is 0.24.

(4.) That the minerals weigh 3.5 tonnes per tonne of iron (or 70 cwt. per ton of iron).

(5.) That their specific heat is 0.20.

Let us use for our unit the quantity required to raise one kilogram of water 1° C.

Now let us suppose that, without altering the other conditions of the furnace in the least, we raise its walls to such a height that the gases are cooled† 22°, and escape at 378° C. instead of at 400° C.

* Journal of the Iron and Steel Institute, November, 1871.

† Although the 24 m. furnace is so high that in point of fact it cools its gases before their escape probably as far as is practicable, and although, therefore, a

This will imply that they transfer to the minerals in the newly added portion of the furnace $22 \times 0.24 \times 6500 = 38,848$ calories, which will raise the temperature of the latter by $\frac{34,848}{3500 \times 0.2} = 50°$ C.

At first sight it would appear that the radiation and conduction of heat from the hearth, and the transfer of heat to the minerals from the volume of gases rushing up the furnace, being such that the minerals arrive at each particular level at a certain temperature, the further transfer of 38,848 calories to them in the upper part of the furnace would cause them to arrive at each successive level with 34,848 calories more than they formerly did, and therefore at a temperature 50° higher, provided we do not derange the working of the furnace; though, as I shall try to show, this may not be exactly true, let us assume for the present that it is.

In accordance with this assumption I have prepared Table I, in the first column of which are the heights of several points above the hearth; in the second column are the temperatures which Bell found to exist at these points; in the third column are the temperatures which will prevail after the uniform elevation of temperature which we are supposing to follow the increase of height of the furnace.

Dividing the furnace arbitrarily into zones of temperature (in the highest of which the temperature is between 360° and 410°, in the next between 410° and 486°, in the next between 486° and 954°, etc.), I have placed in column A the original lengths, L, of the several zones; in column B their lengths, L^1, after the increase of height; and in column C the ratio $\frac{L^1}{L}$. (Of course I cannot give the length of the zone 360°–410° C. after the increase of height, as I have no data for determining the 360° C. level. The temperatures of several of the levels I have arrived at merely by interpolation.)

What strikes one on glancing over the table is that column C shows that the upper and cooler zones of the furnace are increased in a much higher ratio than the lower and hotter ones. Thus, while the distance from where a temperature of 410° prevails to the hearth

further increase of height might not actually effect any farther cooling of the escaping gases, it is perfectly fair for the purposes of my present argument to assume that it would. For my argument has only to do with the *shape* of its thermic curve, which is in all probability so like those of shorter furnaces whence the gases escape much hotter that the inferences which I shall draw from it (and which, of course, apply only to furnaces, the temperatures of whose escaping gases would actually be lowered by an increase of height) will be perfectly applicable to them. The thermic curve of the 14 m. furnace bears out these inferences in every respect.

is lengthened by 2.8 meters (9.2 feet), 2.5 meters (8.2 feet) of this are gained by the region lying between the points where the temperatures of 410° and 486° C. prevail (which I shall for briefness call the zone of 410°–486°). This zone is lengthened about 141 per cent., while the entire region between it and the hearth is lengthened only 1 per cent. The zone 410°–640° is lengthened about 94 per cent., while the whole space which is hotter than 640° is lengthened only 1½ per cent.

TABLE I.

Height above Hearth.	Original Temperature.	Temperature after Increase of Height	Height above Hearth.	Original Temperature.	Temperature after Increase of Height
Meters. Feet.	Cent.	Cent	Meters. Feet	Cent	Cent.
24.38 = 80 00	360°	410°	12 80 = 42 00	891°	941°
21 58 = 70 80	410°		12 48 = 40 94		954°
20 12 = 66 00	436°	486°	11 28 = 37.00	954°	1004°
19 82 = 65.02	486°		10.10 = 33 15		1065°
19 19 = 62 98		640°	9.14 = 30 00	1065°	1115°
18.90 = 62.00	640°	690°	6.66 = 21.85		1336°
17 54 = 57.56		779°	6 10 = 20 00	1336°	1386°
16 76 = 55 00	779°	829°	3 35 = 11 31		1717°
16.13 = 52 93		850°	3 05 = 10 00	1717°	1767°
14 90 = 48 59		891°	0	2226°	2276°
14 63 = 48 00	850°	900°			

Temperature of Zone.	A. L, Original Length of Zone	B. L^1, Length of Zone after Increase of Height.	C. $\frac{L^1}{L}$
Centigrade	Meters. Feet.	Meters. Feet.	
410° to 486°	1 77 = 5 80	4 27 = 14 00	2 41
486° " 640°	0 92 = 3 02	0 92 = 3.02	1 00
640° " 779°	2 13 = 7 00	1 66 = 5.46	0 78
779° " 850°	2 13 = 7 00	1.41 = 4 63	0 66
850° " 891°	1.83 = 6.00	1 23 = 4.04	0.67
891° " 954°	1.52 = 5 00	2 39 = 7.85	1.57
954° " 1065°	2.13 = 7.00	2 37 = 7 79	1.11
1065° " 1336°	3.05 = 10 00	3 36 = 11 30	1 13
1336° " 1717°	3.05 = 10 00	3 06 = 10 54	1.05
Over 1717°	3.05 = 10.00	3.36 = 11.31	1.13
410° to 640°	2.68 = 8 8	5 19 = 17 02	1.94
Over 640°	18.90 = 62 00	19 19 = 62 98	1.01

It will be noticed that the zones immediately beneath the 640° level are decreased by the change, while below the 891° level the zones are lengthened, the increase being most marked in the zones farthest from the hearth.

These effects are due to the shape of the thermic curve. If it were throughout convex to OX, and constantly approaching verti-

cality (but never passing it) as it receded from OY, all the zones would be lengthened by the elongation of the furnace, the percentage of increase being greatest in the upper zones, and decreasing rapidly as we approach the hearth. It is on account of the flexure of the curve towards the axis, at the point 7.7 meters above the hearth, that the zones immediately beneath the level, from 640° to 891°, are shortened. So the zones below the 10.7 meter level are lengthened (the percentage of increase diminishing as we approach the hearth) on account of the convexity of the curve towards the axis OX below that level.

The rationale of this is evident. Where the curve is convex to OX the ratio $\frac{dx}{dy}$ increases as we ascend; that is to say, the temperature diminishes at a constantly retarded rate as we ascend, each degree of temperature exists over a greater length than the one beneath it, and each zone, including a given number of degrees of temperature, is longer than the zone which includes the same number of degrees immediately beneath it.

Now, if we raise the temperature of the furnace uniformly, we establish a new curve of temperature, exactly parallel to the first, such as the curve MM, Fig. 1. Each degree of temperature will now be found at a point farther from the axis OY than before, and each zone a little farther from the hearth. But, as we have seen, on such a convex curve a zone of a given number of degrees of temperature covers a greater length the farther from this axis it is. Therefore, after a uniform elevation of temperature throughout the furnace, each zone situated on the convexity of the curve will be lengthened. Similar reasoning will show that zones on the concave portions of the curve will be shortened by a uniform elevation of temperature.

The ratio of the percentage of increase of the upper zones to that of the lower ones depends only very slightly upon the comparative raising of the temperature of the upper and lower portions of the furnace. If, on the one hand, the increase of temperature caused by such a lengthening were more marked in the lower part of the furnace than in the upper part (and it is very difficult to imagine that it could be), the lengthening of the upper zones would be relatively slightly less, as compared with that of the lower ones, than is shown in Table I. If, on the other hand, the elevation of temperature were greater in the higher regions of the furnace than in the lower (and I shall try to show that it must be), the upper zones would be lengthened still more than we have supposed, and the lower ones still less, as I shall soon show in Table II.

Now, there are two important reasons why all the heat saved by the elongation of the furnace cannot reach the hearth, and, therefore, why the temperature there cannot be raised so much as that of the upper part of the furnace.

TABLE II.

Height above Hearth.	Original Temperature	Temperature after Increase of Height.	Height above Hearth	Original Temperature.	Temperature after Increase of Height
Meters. Feet.	Cent	Cent	Meters. Feet.	Cent.	Cent
24 38 = 80.00	360°	410°	12.80 = 42 00	891°	917°
20 12 = 66 00	436°	470°	11.86 = 38.91		954°
20 02 = 65 69		486°	11.28 = 37.00	954°	977°
19 82 = 65 02	486°		9.51 = 31.19		1065°
19 12 = 62 73		640°	9 14 = 30 00	1065°	1083°
18 90 = 62 00	640°	678°	6 23 = 20 43		1336°
17 31 = 56 80		779°	6 10 = 20 00	1336°	1348°
16 76 = 55.00	779°	814°	3 09 = 10 13		1717°
15.68 = 51 44		850°	3.05 = 10 00	1717°	1723°
14 63 = 48 00	850°	882°	O	2226°	2206°
14.17 = 46 46		891°			

Temperature of Zone	A L, Original Length of Zone	B L¹, Length of Zone after Increase in Height.	C $\frac{L^1}{L}$
Centigrade.	Metres Feet.	Metres. Feet.	
410° to 486°	1 74 = 5.78	4 36 = 14 31	2.48
486° " 640°	0 92 = 3 02	0.91 = 2 96	0 98
640° " 779°	2 13 = 7 00	1 82 = 5.93	0 85
779° " 850°	2 13 = 7 00	1.63 = 5 36	0 79
850° " 891°	1 83 = 6 00	1.52 = 4.98	0 83
891° " 954°	1 52 = 5 00	2 30 = 7.55	1.51
954° " 1065°	2 13 = 7 00	2 35 = 7.72	1.10
1065° " 1336°	3 05 = 10 00	3 28 = 10.76	1.08
1336° " 1717°	3 05 = 10 00	3 14 = 10 30	1 03
Above 1717°	3 05 = 10 00	3 09 = 10.13	1.01
410° to 640°	2 68 = 8.80	5 26 = 17 27	1 97
Above 640°	18 90 = 62 00	19 12 = 62.73	1.01
410° to 850°	6.95 = 22 80	8 71 = 28.36	1.25

First, with regard to the effect of the elongation of the furnace on the rate at which the gases impart their heat to the minerals at the different levels, we must remember that, while the latter are supposed to arrive at each level a little hotter than they did before the furnace was lengthened, the initial temperature of the gases will be very little altered, since the O and N they contain in the lower part of the furnace (which come exclusively from the blast) start at the same temperature as previously, the C alone coming from the minerals,

and, therefore, having a slightly higher temperature. The C, however, constitutes only about one-seventh of the initial weight of the gases, so that their initial temperature will be raised only about one-seventh as much as the temperature of the minerals is in the neighborhood of the tuyeres. Of course this raising of the temperature of the minerals more than that of the gases, and thus bringing their temperatures nearer together, will cause the transfer of heat from the gases to the minerals to take place less rapidly; thus the gases will give up less of their heat in the lower regions after the increase of heat than before it, and have so much the more heat to give to the minerals in the upper regions, and thus raise the temperature of the upper regions still further.

Moreover, as the size (and with it the radiating surface) of each zone is increased, the amount of heat lost in each zone by transmission through the walls and consequent radiation from the outside of the furnace will be increased. Therefore, less of the additional heat transferred from the gases to the minerals by the increase of height will get to the lower zones than to the upper ones, each zone getting a little less of this additional heat than the one above it. Bell considers that the loss by radiation is 182,808 calories; according to this, if, as we have supposed, our furnace is lengthened 14 per cent. below the 410° level, the loss by radiation would be increased by $\frac{182,808 \times 14}{100} = 25,593$ calories, the total gain of heat by the lengthening of the furnace being, as we have seen, 34,848 calories. But as most of the increase of length would be in the upper and cooler parts of the furnace, from which radiation is much less rapid than from the hotter parts, probably only about 15,000 more calories will be lost by radiation after the elongation than before it. Thus, it seems safe to conclude that the elevation of temperature caused by this lengthening of the furnace will certainly not be greater in the lower part of the furnace than in the upper, but that it will probably be less.

To illustrate the effects of this greater elevation of the temperature of the upper zones than that of the lower ones I have prepared Table II, on the extreme assumption that the lengthening of the furnace will not raise the temperature of the hearth at all, but that the elevation of temperature (assumed to be 50° at the throat) is less and less at each successive lower level, being finally nil at the hearth.

The results are here practically the same as in Table I, though the lengthening of the upper zones is comparatively slightly greater than in that table. Thus the zone 410° to 640° is lengthened here

97 per cent. against 94 per cent. in Table I, while the distance from the 640° level to the hearth is practically unaltered.

Now, if the percentage of increase of the upper zones be greater than that of the lower ones, and therefore greater than that of the furnace as a whole, both (1) when all the heat gained by the lengthening reaches the hearth as in Table I, and (2) when none of this heat does as in Table II, of course it must be greater in any intermediate case, in which a portion of it reaches the hearth.

Since previous reasoning has shown us that the elongation of the furnace is most unlikely to raise the temperature of the upper zones less than that of the lower ones, but that we have good reason to expect the reverse, we may conclude that the ratio of the percentage of increase of the upper zones to that of the lower ones will certainly not be less than it is shown to be in Table I, but that it will, if anything, be slightly greater.

Indeed, even if the temperature of the lower part of the furnace could be raised slightly more than that of the upper part (which seems hardly possible), the results of Table I would be only slightly modified.

Coming now to the case of the 14.6-meter furnace, I have ventured to alter its curve a little, not that it is necessary to do so in order to bear out my reasoning, but because, as I understand Mr. Bell, he has purposely distorted it to illustrate another point. By referring to the original curve (*Journal of the Iron and Steel Institute*, November, 1871), it will be seen that it *recedes* from the vertical axis, as it rises above the 11.2-meter level, which would imply that the furnace is hotter at the mouth than at a point 4 meters lower down. This seems impossible under normal conditions, and the text shows that Mr. Bell does not mean to imply that the furnace is actually hotter at the top than below it.

Assuming 557° C. as a probable temperature for the mouth of the furnace, I have constructed Table III, placing, as before, in the first column the distances of several points above the hearth, in the second the temperatures found at those points by Bell, and in the third the temperatures which would exist after an increase of height sufficient to cool the gases to an extent which would raise the minerals 50° C. (I have assumed that none of the heat thus gained will reach the hearth, but the results would not be materially different if we supposed the hearth also to have its temperature raised 50° C., nor yet if any other probable temperature were assumed for the escaping gases.)

TABLE III.

Height above hearth.	Original temperature.	Temperature after increase of height	Height above hearth	Original temperature.	Temperature after increase of height
Meters. Feet	Cent.	Cent.	Meters. Feet.	Cent.	Cent.
14.6 = 48 00	557°	605°	8 6 = 28 35	954°	954°
13 1 = 42 65		640°	8 2 = 27 00		981°
12 8 = 41 65	605°		6 6 = 21 79	1039°	1039°
11.3 = 37 00	640°	677°	6 1 = 20 00		1059°
10 5 = 34 49		850°	3 14 = 10 28	1410°	1410°
10 3 = 34 00	850°	884°	3 05 = 10 00		1420°
10 11 = 33 24		891°	O	2079°	2079°
9 1 = 30 00	891°	921°			

Temperature of zone	A. L, original length of zone	B L', length of zone after increase of height	C $\frac{L^1}{L}$
Centigrade.	Meters Feet	Meters. Feet	
605° to 640°	1.41 = 4 64	1 62 = 5 35	1.15
640° " 850°	0 91 = 3 00	2 49 = 8 16	2 72
850° " 891°	1 22 = 4 00	0 37 = 1.25	0 31
891° " 954°	0.91 = 3 00	1 49 = 4 89	1 63
954° " 1039°	2 13 = 7 00	2 00 = 6 56	0 93
1039° " 1410°	3 05 = 10 00	3 37 = 11 51	1.151
Above 1410°	3.05 = 10 00	3.06 = 10 28	1 028
605° to 850°	2 32 = 7.64	4 12 = 13 51	1.77
Above 850°	10.36 = 34 00	10 49 = 34.49	1.01

Here, as in the case of the 24-meter furnace, we find the cool zones lengthened much more than the hotter ones; the zone of 605° to 850° is lengthened about 77 per cent., while the whole region below it, and hotter than 850°, is lengthened only about 1 per cent.

A comparison of the lengths of the several zones of the 24-meter and the 14-meter furnace which I have made in Table IV bears out fully the previous reasoning, and shows that, whether it be sound or not, its conclusions are in accordance with facts. Obviously the validity of this comparison does not depend upon any of the assumptions I have made.

In the second and third columns of Table IV are the lengths, L and L^1, of the several zones in the 14.62-meter and in the 24-meter furnaces respectively, in the fourth are the ratios, $\frac{L^1}{L}$, and in the fifth the excesses of L^1 over L. The length of that portion of the furnace which is cooler than 850° C. is nearly three times as long in the

24.3-meter as the 14.62-meter furnace, while the region hotter than 850° C. is only one-quarter longer in the former than in the latter.

Table IV.

Temperature of zone.	L, Length of Zone in 14-meter Furnace.	L^1, Length of Zone in 24-meter Furnace.	$\frac{L^1}{L}$	Excess of L^1 over L.
Centigrade.	Meters Feet.	Meters. Feet.		Meters. Feet
Under 640°	0	5.48 = 18	∞	5.49 = 18
Between 640° and 850°	4.27 = 14	4.27 = 14	1	0 = 0
" 850° " 891°	1.22 = 4	1.83 = 6	1.5	0.61 = 2
" 891° " 954°	0.91 = 3	1.52 = 5	1.67	0.61 = 2
" 954° " 1039°	2.13 = 7	1.63 = 5.36	0.77	0.50 = 1.64
" 1039° " 1410°	3.05 = 10	4.14 = 13.58	1.36	1.09 = 3.58
Over 1410	3.05 = 10	5.58 = 18.06	1.81	2.46 = 8.06
Under 850°	3.35 = 11	9.75 = 32	2.91	6.40 = 21
Over 850°	11.28 = 37	14.63 = 48	1.29	3.35 = 11
Under 891°	5.49 = 18	11.58 = 38	2.11	6.10 = 20
Over 891°	9.14 = 30	12.80 = 43	1.40	3.36 = 12

Moreover, two-thirds of the total excess of length of the 24.3-meter furnace goes to lengthen the region cooler than 850° C., and only one-third to lengthen the region hotter than 850° C.; and while the 24-meter furnace is only 67 per cent. longer than the 14-meter, the region in the former, which is cooler than 850° C., is 2.91 times as long as the corresponding region in the hotter furnace.

Since the lengthening the upper zones in a greater proportion than the lower ones, by an increase in height, depends solely upon the curves being mainly convex to the axis *OX*, we should expect it even had we not these examples of the Clarence furnaces. For the general convexity of the curve to *OX* merely means that the temperature increases on the whole at an accelerated rate as we descend in the furnace. Most of the heat is generated in the hearth, near the tuyeres, by the combustion of C to CO. That portion of this heat which is carried to the rest of the furnace by radiation and conduction will, of course, tend to produce a rapidly accelerated rate of increase of temperature as we approach the tuyeres; that is, as we approach a place where combustion is occurring, we may, in general, expect the temperature to increase at a highly accelerated rate.

Since a second and much less important source of heat is the combustion of CO to CO_2 with the O of the ore in the upper part of the

furnace, we should expect to find, as we do, a convexity of the curve from the throat to the level where this combustion is most active, which is at the 19.50-meter (64 feet) and 10.97-meter (48 feet) furnaces respectively. But this convexity would naturally be less marked in this combustion to CO_2 [which is spread out over 12 meters (40 feet) in the 24.3-meter (80 feet) furnace, and causes slight elevation of temperature, owing to the simultaneous absorption of heat by the reduction of the iron oxide] than in the combustion of C to CO, which is entirely effected within a very short distance of the tuyeres.

II.

Let us go a step further, and look at the practical bearing of the facts I have tried to establish:

We know that the productive power of a furnace is practically limited, that when we try to increase its production beyond a certain point we first lower the grade of the product, producing closer iron poorer in carbon. If we still further hasten it we eventually produce white iron, then a black, scouring cinder of silicate of iron, and finally our furnace chills.

These phenomena tell us that we have two elements which limit the productive power of the furnace. First, the cooling of the hearth, as indicated by the lowering of the quality of the iron, and, finally, by the danger of chilling; secondly, the tendency to form scouring ferrous slag, which endangers the structure of the furnace itself.

Considering now the first of these elements, we know that, since the grade of the product is dependent upon the temperature of the hearth, the rate at which we can produce iron of any particular grade is limited by the fact that, if we drive the furnace beyond a certain speed, we make the hearth too cold to produce iron of that grade.

Now, how is it that increasing the speed of the furnace cools the hearth?

The heat in the hearth is derived from—

(1.) The heat of the blast.

(2.) The combustion of C to CO; and

(3.) The heat intercepted by the descending column of minerals from the gases, and returned to the hearth.

It is consumed—

(1.) In melting the iron and slag.

(2.) In heating the gases; and

(3.) In direct radiation and conduction.

Now, when we increase the speed of our furnace, we increase the first two elements of the heat requirement of the hearth; that is, we have more iron and slag to be melted and a greater weight of gas to be heated per minute. We also increase two elements of the heat development in precisely the same ratio, provided we do not derange the working of the furnace; that is, the weight of blast, and with it the heat brought in by the blast, are increased at the same rate, as is also the weight of C burned to CO.

The third element of the heat development will be increased in nearly the same ratio, as a corresponding greater mass of minerals will arrive at the hearth per minute. They will not, however, be at quite so high a temperature, as the gases will pass through the furnace more rapidly than before, and will not give up their heat quite so fully to the minerals.

The third element of the heat requirement, viz., the loss by radiation and conduction, will be hardly increased at all. We should, therefore, on the whole, expect that an increase of speed would be followed by a slight rise of temperature.

The reason why the hearth is cooled is that, when we try to push the production beyond a certain point, we do derange the working of the furnace to some extent, and thereby lessen the supply of heat from the second source, the combustion of C to CO, and also from the third and chief source, that intercepted and returned by the several descending minerals. The quantity of heat they will bring to the hearth will depend upon the amount of heat generated in the furnace, upon the region of the furnace where it is generated, and upon the length of time the minerals and the gas are in contact.

When the speed of the furnace is increased too much, the iron oxide is hurried through the upper cool zones, in which the CO_2, formed by the reaction,

$$(1.)\ FeOx + yCO = FeO\,(x-y) + yCO_2,$$

is not liable to be reduced by the reaction.

$$(2.)\ CO_2 + C = 2CO.$$

[Reaction 1 takes place very readily at low temperatures; but reaction 2 does not readily occur at temperatures much below 800° C. (1472° F.), and is greatly favored by hotter temperatures.] The result of this is that a greater or less portion of the oxides remains to be reduced lower in the furnace, at temperatures so high as to

favor the reduction of the resulting CO_2 by reaction 2, which necessarily causes an enormous loss of heat.

Secondly, as the formation of CO by the succession of reactions 1 and 2 is accompanied by a very considerable lowering of temperature, an undue hastening of the speed of the furnace not only increases the great loss of heat by reaction 2, but also causes this lowering of temperature to take place nearer and nearer to the hearth. Now, of course the nearer to the hearth such a lowering of temperature takes place, the stronger is its effect in lowering the temperature at which the descending column of minerals reaches the hearth.

Thirdly, reaction 2, which inevitably takes place when the ore is hurried through the cool zones too fast to be properly reduced in them, causes a great and useless consumption of carbon, leaving just so much the less to be burned at the hearth, and thus diminishing the second of the sources of heat previously enumerated.

Fourthly, the increase of speed diminishes the time during which the gases are in contact with the minerals, and thus lessens the heat intercepted by the latter.

Summing up these points, the fall of temperature in the hearth is mainly, or almost wholly, due to the ore's remaining too short a time in the cool zones of the furnace.

It may be urged very plausibly that if the lowering of the temperature of the hearth be the only thing that limits the productive power of the furnace, it is an obstacle which need not give us much trouble. All that is necessary to overcome it is to erect a pair of Mr. Whitwell's most excellent hot-blast stoves, and to increase the sensible heat introduced by the blast. No doubt they do increase the production of furnaces in this very way in many cases. Yet there is a limit even to the temperature attainable by Whitwell stoves; and beyond this limit it is plain that we will again be in danger of cooling our hearth too much, if we attempt to drive our furnace too fast.

Coming now to the second of the elements which we have been considering as limiting the productive power—the tendency to produce ferrous slag—we find that it is wholly due to a too short exposure to a low temperature. If the iron oxide is hurried through the cool zones so fast that it arrives at the temperature of incipient fusion before it has been thoroughly reduced, it will then unite with the silicious matter of the charge to form a black scouring slag of ferrous silicate. This slag is very fusible, but very difficult to reduce. If

the speed of the furnace is very high, and if the ore is exposed to a temperature below the point of fusion for a very much less than sufficient time, the amount of unreduced iron oxide which will thus enter the slag will be very great, and we will have a ferrous slag with a large percentage of base, which, having a strong affinity for silicic acid, attacks the brickwork lining of the furnace. and thus imperils the structure itself. If a lining could be devised which would resist the chemical action of such a slag, such as bauxite lining, it would still be foolish to run the furnace in such a way as to produce a highly ferrous slag, as it implies the waste of a very considerable portion of the iron oxide of the charge. It is probable that the tendency to produce white iron when a ferrous slag is formed is in part due to the ferrous oxide of the slag being reduced at the expense of the carbon of melted iron, when the two lie in contact with each other in the crucible of the furnace.

Now this formation of a ferrous slag can only be avoided in one way, and that is by exposing the iron oxide to the reducing action of C and CO, at a temperature below that of incipient fusion, for a length of time sufficient to insure its practically complete reduction, which means having the cool zones sufficiently long. Raising the temperature of the blast may prevent the cooling of the hearth to a certain extent, but it can only favor the formation of ferrous slag, by raising the general temperature of the furnace, and so shortening the cool zones, and bringing the iron oxide to the temperature of fusion sooner after its entrance into the furnace. It is probable that a long exposure in the zone of carbon deposition (an action which, according to Bell's researches, takes place only at low temperatures, and ceases altogether at a full red heat) is absolutely necessary, at least if we wish to obtain anything but the very hardest and whitest iron. Here, again, a higher temperature of the blast would merely shorten the zone of carbon impregnation.

Therefore, we may say that a sufficiently long exposure to a low temperature in the upper part of the furnace is absolutely necessary, and that without it we cannot prevent the formation of scouring slag. Moreover, having this, we are protected against the great loss of heat which the reduction of CO_2 would cause, and we allow the iron oxide to become properly impregnated with carbon. Of course if we seek for great speed this exposure can only be attained by having the cool zones very long.

Having sufficiently long cool zones, it seems as if the length of the hot zones were immaterial. For their function is merely to heat

and fuse the iron and slag, and there is every reason to believe that no desirable action, either chemical or mechanical, takes place in them for which much time is needed; certainly none which requires more time than it is sure to get, provided the ore remains long enough in the cool zones.

Indeed on some accounts it is desirable not to expose the ore to a high temperature any longer than is absolutely necessary; for it is only at very high temperatures, apparently, that phosphoric and silicic acids are reduced, and anything which shortens the stay of the ore in the zones which are hot enough to permit the reduction of these acids has a tendency to lessen the amount of phosphorus and silicon which will enter the pig iron. Of course, when we seek for a high percentage of Si in our product (a thing generally to be avoided, although sometimes required for the Bessemer process, as in Hunt and Wendel's method), this observation does not apply.

Thus, it seems probable that the length of the hot zones does not limit the productive power of the furnace (unless, perhaps, for highly siliconized pig iron), but that it is determined by the length of the cool zones. For instance, if we are running a furnace so fast as to be in danger of chilling, and are threatening its destruction with a scouring cinder, we can return to the normal condition of things, either by letting the minerals pass through the cool zones more slowly (which means diminishing our production), or by lengthening these zones so much that the minerals will remain in them a proper length of time in spite of their rapid rate of descent.

Now, I have tried to show that a slight increase of the length of the furnace will greatly enlarge the cool zones, and that a rate of descent which would be destructive in a short furnace might be made perfectly practicable by the great increase of the size of the cool zones, which is caused by a slight lengthening of the furnace. Thus, if we wish to triple the productive power of our 14-meter furnace, and for that end to triple the length of its cool zones, it will only be necessary (as regards length alone) to elongate the furnace by something like 67 per cent. For, as we have already seen, although the 24-meter furnace is only 67 per cent. longer than the 14-meter furnace, yet the space in the former which is cooler than 850° C. is 2.91 times as long as the corresponding space in the latter. If this should enable us even to double the production of the furnace (all the other elements which are necessary for such an increase coexisting), the tendency to reduce silicic and phosphoric acids would probably be very much lessened by the now doubled rate at which the minerals

descend through the several zones; for the length of those zones which are hot enough to permit the reduction of these acids would be hardly increased at all by the elongation of the furnace, and the stay of the minerals in them would thus be greatly shortened.

We have not such exact information about the temperature at which manganese begins to be reduced as to enable us to foretell whether its reduction would be favored or not by such a change in the relative sizes of the different zones of the furnace as we have been considering. But it seems highly probable that at least its reduction would not be hindered so much as that of silicon and phosphorus.

And this, I believe, is the way in which increasing the height of furnaces has sometimes led to very much more than proportionate increase of production; and I infer that, even though lengthening a furnace may cool the gases very slightly, and produce no saving of fuel, it may yet greatly increase its productive power without necessitating a proportionate increase of cost of construction or of labor.

Mr. Thomas Whitwell.—Mr. Chairman, we had at our own furnace, on the 24th of September of last year, the temperature of the escaping gases taken. The temperature of gas set forth on the blackboard is 400° Centigrade. The actual heat in the gases at the top of our 75-feet furnaces (23 feet and 22 feet in diameter respectively; hearth 8 feet and 9 feet respectively in diameter) varied from 400° to 480° Fahrenheit. The furnace charge was ten feet down below the level of the platform. This may have been the result of using superheated blast. Mr. Bell shows, in England, that so long as the escaping gases are above the temperature of 450° Fahrenheit, so long they have an active effect in the reduction of the minerals. As soon as the escaping gases are proved to be below 450° Fahrenheit, no further increase in the height of the furnace will be of any good. In our case, the gases come off of a 75-feet furnace with charge 10 feet down at a temperature of 400° to 450° Fahrenheit, and therefore it shows that we are quite as high at 75 feet as there is any good effect to be gained. I may say that at the Consett furnaces we have carried out a very interesting series of experiments. We have there six furnaces, all supplied with superheated blast on my system. Nearly all of the furnaces are of different dimensions but of the same height, namely, 55 feet from the bottom of the hearth to the top of the platform, and are all supplied with the cup and

cone system of charging. The furnaces have all 8-feet hearths. The diameters of the boshes vary from 20 feet to 22 feet 6 inches. The dimensions of the top of the furnaces vary, but we may take a line 9 feet below the charging platform in each furnace, and we have diameters varying from 20 feet down to 14 feet 9 inches. The amount of coke that is burned in blast-furnaces depends to a very large extent, in the first place, on the composition of the materials, but to a very much larger extent on the charging of the furnace itself. And in considering the question whether in blast-furnace practice it is necessary to have a high or a low temperature of blast, we must also take into consideration all the other elements that would change the result in working it out. In Mr. Bell's paper, that was read here during the summer, I think he states that, at the Glendon furnace, with a temperature of 800° to 900° of blast, he found the same result as he found at the Cedar Point furnace with a temperature of about 1300° of blast. Therefore he would say, What is the good of extra heat of blast? I do not remember that Mr. Bell gave the composition of the iron ores at Cedar Point, which I believe to be totally different from those at Glendon. He did not give any dimension of the furnaces of the charging department or anything else at Cedar Point. Hence, unless we know all these different conflicting points, I think the engineer should be careful in coming to a conclusion.

In 1869, four furnaces were blown in at Consett. (Demonstrating on blackboard.) I place the numbers on the furnaces in the order in which they stand in the works. The first furnace, No. 4, was altered and had four fire-brick ovens given to it; it was 55 by 20, with 8-feet hearth, and had 5 tuyeres 4½ inches diameter each, and a pressure of blast of 3½ pounds at the tuyere. Their first furnace at the point 9 feet below the charging platform was 14 feet in diameter, and the temperature of the gases passing away underneath the platform was 478° Fahrenheit, the temperature of the blast being 1422° as proved by Mr. Bell. You will notice the hearth in each furnace is 8 feet diameter and 4 feet deep only, and at a height of 4 feet, or perhaps, to be accurate, I should say 4 feet 8 inches, the line sets away off to the bosh. That furnace has been in blast six years and nine months, and has made upwards of 174,000 tons of gray iron. It is now out. They are putting a new hearth and bosh in it.

No. 5 furnace was built after No. 4, for the purpose of trying to make more iron than No. 4 at that time, after 6 months' work, was making. Therefore the bosh, while the height is the same,

was increased to 22 feet 6 inches in diameter. The hearth was the same, 8 feet; the diameter, 9 feet below the top was 20 feet. It was found that although the cubical contents of that furnace were larger, yet the same quality of metal as in No. 4 furnace could not be obtained. It had still 5 tuyeres, each was $4\frac{1}{2}$ inches in diameter; the pressure of blast was $3\frac{1}{2}$ lbs., and yet for some reason or another that furnace would not make the quality. While No. 4 made only two per cent. of white iron, No. 5 made 22 per cent of white iron. Of the total amount of iron made in No. 4 furnace there was 220 tons of white iron to 20,000 tons of gray forge. We were going as fast as we could and with the same heat of blast, and, notwithstanding the 2 feet 6 inches increased diameter of bosh and larger cubic capacity, we did not exceed 480 tons a week with that furnace. We drove up to 580 tons a week with this smaller one, No. 4, thus showing that there was some element in the smaller furnace that not only gave perfect regularity in the working of the furnace, but a very much larger quantity of iron. We tried by increasing the quantity of blast in No. 5 furnace, giving her five 5-inch tuyeres on the same pressure of blast, but with no result at all.

Question.—Did you have independent engines to work these furnaces?

Mr. Whitwell.—No, they were worked off the same blast main. That is the system in England; if the new furnace gets into bad order, you go on at the same pressure until it gets right again. The furnaces at Consett are all in one line, connected with one blast main, on one pressure. We found then that the large furnace, 22 feet 6 inches in the bosh and 20 feet under the bell above, working against a furnace somewhat smaller, 20 feet in the bosh and 14 feet under the bell, produced less favorable results, and that, therefore, the increase of size did not give us any advantage. The blast of No. 5 furnace was kept to 1500°, the stoves being 3 feet 6 inches higher than those of No. 4, No. 4 having the first set of stoves put up, and these only 25 feet high. In the book that Mr. Bell brought out on the *Smelting of Iron,* he says that he was consulted about that time, and that he had advised the furnace manager to lower the heats and see if they could not obviate that irregularity; that he understood his advice was taken and they were doing rather better. That book was stereotyped week by week as the papers were written, and hence it was impossible to correct it on the same page afterwards. I saw the manager of the works and said to him, "I understand that you have lowered your heats." "No,"

he says, "I haven't. I am working at 1500 degrees." I said, "It is now printed in the Journal of the Institute of this week that you have lowered your heats and got a better result." He says, "Well, all I can say is that Mr. Bell met me in London, and said, 'How are you going on?' and I said, 'We are going on rather better.' Mr. Bell was thinking about the hot-blast; I was not." And hence, when one idea rose in Mr. Bell's mind, he printed it in his book, and afterwards, as a footnote some 300 pages after, said that it was possible in regard to No. 5 furnace that there may have been something in the structure of the furnace that had had something to do in giving these results. I may say, though, that at this time, in order to discover the reason why one furnace should make more iron and with greater regularity than the other, the drawings of No. 5 were sent to Mr. Bell, and he was asked if there was anything wrong about them. His opinion was that they were perfectly right, and that there was no reason in the world why the furnace should not work well. I may say that the bell and cone of No. 4 was 10 feet 6 inches in diameter. The cone of No. 5 was 12 feet 6 inches. It being found, however, that the best results were got by keeping up the heat, that furnace has now been running for five years at the temperature of 1500°, and it is still in blast.

Question.—Were the angles of these boshes the same in both of these furnaces?

Mr. Whitwell.—Yes, 68 degrees. The next furnace reconstructed was No. 2. Our system in England has been forced upon us, that is to tear down the old furnaces and put up new ones. It has been the case in our own works where we have had to pull down 60-feet high furnaces and put up 75-feet furnaces, simply because the others would not work economically. We have to look after the pennies over there. No. 2 furnace at Consett was next reconstructed. The managers of the company considered that one thing was proved, namely, that No. 5 was too large for the materials they were charging. The materials, I should say, were mixtures of Cleveland ores calcined and the Cumberland hematites. The Cumberland ores will run on good samples sixty per cent. metallic iron, and at the time of which I speak it was customary to charge these furnaces with two-fifths Cumberland ores and three-fifths of the Cleveland calcined ores, the whole being a mixture requiring about 46 English cwt. of 112 pounds of ore to make a ton to contain 2240 pounds of iron.

No. 2 furnace was taken in hand next. The height was kept

the same. They asked me my opinion. I said, "While No. 4 is doing so well, and No. 5 is doing moderately well, I would copy No. 4 and wouldn't make the other any larger." But as Mr. Bell had told them that the dimensions ot No. 5 were all right, they thought they would split the difference and put in half and half, and therefore they adopted 21 feet bosh, 8 feet hearth, 5 tuyeres, again, 4¼ inches diameter at the nozzle, and 3½ pounds pressure of blast. They thought, however, that the angle of the bosh was too flat, and therefore they increased that angle to 71°. The cone in the top of the furnace was 11 feet in diameter, and the diameter at the upper part of the furnace was 18 feet, being a compromise between No. 4 and No. 5 furnace, the diameter of the bosh being 21. The depth of the hearth was still 4 feet 8 inches. This furnace, on being blown in with the same sized stoves as No. 5, was found to work fairly well, but after three months they found that there was 18 per cent. of white iron made still while endeavoring to get gray forge, or what I believe you call No. 1 mill. I may say that the Consett Company do not sell any pig iron, having large plate mills of their own, turning out 1200 tons a week, chiefly for ships and locomotives, etc., together with government work. They require good iron for it, and work in their own mills all the metal the furnaces can make. No. 2 and No. 1 were reconstructed at the same time, but No. 2 was blown in first to see what result could be got by making a compromise between 4 and 5. Finding still that they had 18 per cent. of white iron, they then finished No. 1, and did it by pulling down the work already laid in at the top to a distance of ten or fifteen feet, and reduced the size under the bell to the same as No. 4 furnace. The height was still the same; bosh 21 feet, and the other dimensions as I have given them. The diameter was 14 feet 9 inches—9 feet below the charging platform; angle of bosh 71°, hearth exactly the same as the preceding cases. The percentage of white iron, on the furnace being blown in, fell to about two, thus showing that, while the bosh had been made a little larger—the angle at the boshes had been made steeper—the upper part of the furnace exercised a very important influence upon the whole. About this time I was travelling with Mr. Bell and a director of the Consett Company, and the question arose with regard to the height of the furnace there. Mr. Bell observed that, if the furnace had been made 30 feet higher, and the temperature of the blast had been kept to about 900°, there would be as good economy as at present. I asked Mr. Bell, "Would you guarantee that you

could get 500 tons of iron a week with the same coke as at present?" He said, "I wouldn't guarantee you anything at all." I said, "What would be the saving in coke with our present heats if you put them up 30 feet higher?" He said, "You are so near the mark I don't suppose you could gain $\frac{3}{4}$ of a cwt. in coke." The gases were all down as near as possible at a point where the gases ceased to have any action in reducing the oxide of iron.

Therefore we were working as economically as possible, or very nearly so, while at the same time we were producing a very large amount of iron. Now, Nos. 1, 2, 3, 4, and 5, produced on an average 25,000 tons per annum, and a blast seems to be likely to last 7 to 8 years. Since then another furnace has been built, to wit, No. 6, almost exactly similar to No. 1. No. 3 furnace heretofore has been very similar to No. 2, except that it has 20 feet bosh, and not 21 feet. It was constructed first, or rather reconstructed, from the old furnace in 1868, and the Player hot blast put to it as the best approved system at that time. Owing, however, to the fact that the five hot blasts were insufficient to supply five $4\frac{1}{2}$ tuyeres with $3\frac{1}{2}$ lbs. of blasts, they had, in order to maintain 700° of heat, to make constant renewals of pipes. It was found, however, that the coke was always 5 cwt. too high with heats of 900° F. This year the five Player stoves were torn down, and four fire-brick stoves put up in their place, so that the whole works, with six furnaces producing that number of tons per annum, are all at work on the fire-brick system.

Turning to another question with regard to height of furnace, I may say that at Seraing, in Belgium, John Cockerill & Co. have reconstructed their furnaces, and have built two 60 feet high at the charging platform, 16 feet bosh, surrounded with a centre gas tube for taking out the gas, and also with a *trémie* or curtain placed around inside the upper part of the blast furnace. These furnaces were designed to work to the greatest possible economy in making Bessemer steel, and they have attained that result. They were the first in Southern Europe (although I believe something had been done in Sweden in that way), to run the pig iron directly into the Bessemer converter, and so soon as they were blown in, each furnace being supplied with four Whitwell hot blasts on the same plan as Cedar Point, N. Y., they began to give wonderful results, and it was not long before the Seraing Company took an order for 8700 steel rails out of the teeth of all the English makers, and it set them on tiptoe to find out how it was that steel could be produced

so much cheaper. I met Mr. Snelus on his way to Seraing travelling with Mr. Lancaster, then managing director. It was merely a question of having the furnaces built to the right size to work their materials, and they arrived at perfect regularity in the heat of the blast, and almost perfect regularity in the product of the furnace. I regret that I have not a letter received from Mr. Philippart, the chief engineer at Seraing, about six months ago. He, said, however, that for the two years that they had been in blast making Bessemer iron and running directly into the converter, they had not once had a hang in the furnace or a scaffold; that with the system of charging a furnace only 60 feet in height the charges descended perfectly like sand in a sand-pit, equally on all sides—no slipping or anything of the kind. They kept up the temperature of the blast to 1400° F., and were producing No. 1 Bessemer iron with 107 pounds of coke to 100 pounds of iron. Those results show what can be done with an ore that only averages 53 per cent. of metallic iron. A short time ago I met Professor Jordan of Paris, who was director of the works of Société of Denain, near Valenciennes, where are two furnaces also supplied with my hot blasts, and he assured me that they were working with under 2240 lbs. of coke for 2240 lbs. of Bessemer iron. These furnaces also are 60 feet high and 16 feet bosh. It would appear, then, from all I can see, that while the height of furnace may in some cases increase the production, yet at the same time regularity in the working of the furnace, proper dimensions of charging apparatus, and of course regular pressure, seem also to have a very great influence upon its going, and that the comparatively small furnace working in itself perfectly well will often give a larger quantity of iron than a much larger furnace might do. Height of furnace does not always give increased make. A short time ago I met a director of Bolckow, Vaughan & Co. at Middlesbrough, where they have several furnaces 93 feet high, and he told me that in his opinion, if they were building new furnaces, they would not go the height they have at present.

The Rosedale and Ferryhill furnaces run up to 103 feet high, and in two new ones lately put to work they had not exceeded 95 feet in height, thus showing that they had exceeded the best point. It seems moreover to be generally conceded that the quality of coke is not so good as it used to be, owing to the men having received higher wages the last four years, and at the same time to the careless habits of working in the Cleveland district, the small dust of the

coke tending to fill up the furnaces and the interstices between the materials by which the gas ought to ascend, making fast driving in a furnace very difficult; and thus a short furnace with proper heat of blast will often give a larger make in proportion than a high furnace, and with as good economy.

The Tees Bridge furnaces, near Stockton, were put to blast two or three years ago, 65 feet high, and worked with Cleveland iron stone only. It would have been thought that they could not equal tall furnaces 85 feet high. They have, however, been able to hold their own, having my superheated blast, and on a recent occasion a conversation took place at the Middlesbrough Exchange, where Mr. Bell asked a managing director of the company how much coke they were using. He said 21 cwt. per ton of iron. Mr. Bell said, "Now, Mr. Richardson, I have been in the trade a good many years, and have had a good many furnaces, and I think you had better tell that to somebody else." "Well," said he, "the furnace manager is here." He saw the furnace manager, who repeated the same thing, and asked him to go up and see the books. This was not long before Mr. Bell's visit to America. A month afterwards I saw Mr. Bell and asked him if he had been up there. He said no, but he had sent his manager, Mr. Thompson, who had spent a whole forenoon there, and said those furnaces were doing as well as any other furnaces in the district, and for the size were making proportionately more iron than the other furnaces in the district, and the only reason seemed to be that the blast got through easy.

The result, therefore, seems to be that in all cases the height of the furnace must be proportionate to the size of the material, and also that, in order to arrive at a correct conclusion with regard to the effect of the heat of the blast, we must know all the different details with regard to the size of the furnaces, the slope of the boshes, the charging apparatus; and no doubt one great thing is the size of the iron ore. In Cleveland the size of the calcined ore averages about six inches in cube, hard and refractory in nature. Hence it has happened, that with ordinary cast-iron hot blasts, it has been necessary to build up furnaces to a great height, even running the risk of the furnace making less iron, owing to the blast not getting through; and when all has been said and done we have achieved the same, or equally good results, in economy by small furnaces 65 feet high, with the fire-brick hot blasts.

One word now with regard to the durability of the hot-blast stoves. At Consett furnace No. 4 has been running 6¾ years and making

26,000 tons per annum, and the same stoves are going to be used again for the next blast, which probably will be another seven years. The bricks are there as true as they were at the beginning, seven years ago. They are not putting any new bricks in. They are raising the stoves 3 feet 6 inches, and making them equal to the others in the place. As far as we can see, there does not seem likely to be anything exceeding 5 per cent. per annum expended in maintenance. Certainly by giving the same stove fourteen years' work instead of seven, it seems as if the depreciation and repairs were going to amount, in the long run, to a very small figure.

Question.—Have you any experience with furnaces 22½ bosh and 75 feet high?

Mr. Whitwell.—Yes. The Cumberland Smelting Company, at Millom, built two furnaces lately 70 feet high for making Bessemer pig. They were 20 feet bosh, 7 feet hearth, and 14 feet under the bell, and I may say that the engineer of those furnaces put up the first set of my fire-brick stoves at Consett. Those furnaces are now producing, with a material requiring 34 cwt. of Cumberland ore to make a ton of iron, 490 tons of Bessemer pig per week with the consumption of 19 cwt. of coke. They told me 18, but I am willing to put a cwt. on that. I do not think that there are any Bessemer furnaces in England that can equal those. The results of the first two furnaces have been such that the company have pulled down three old furnaces 85 feet high, put in two new ones, the same height as those supplied with hot blasts, and they have within the last two months pulled down three other old ones, and are putting in two more of the same dimensions, so as to have six furnaces of the new size with 23 fire-brick hot blasts, since it was very evident in their case, using 19 cwt. of coke only, that there was a large economy, and that the difference in the cost of hot blast would cover itself in the first six months of the life of a furnace.

I must apologize for the length of my observations, and for having diverged from the temperature of the waste gases to certain conditions which govern that temperature. The subject of the working of the blast furnace, however, is a most interesting one, and this must be my excuse for taking up so much of your time.

CAN THE COMMERCIAL NOMENCLATURE OF IRON BE RECONCILED TO THE SCIENTIFIC DEFINITIONS OF THE TERMS USED TO DISTINGUISH THE VARIOUS CLASSES?

BY WILLIAM METCALF, PITTSBURGH, PA.

It is the object of this paper to oppose unnecessary changes, and the introduction of new and confusing terms.

From the earliest times of which we have any record on the subject, iron has been divided into general classes. Whether iron was first known in the form of wrought iron or of steel, is a matter of no importance; but at the time when cast iron first became a prominent article of commerce, wrought iron and steel were old products—steel, at that time, being generally made from wrought iron by the process of cementation. As steel was then properly defined as iron containing more carbon than wrought iron, so cast iron was appropriately defined as iron containing more carbon than steel.

Until the year 1776, when Huntsman first began the manufacture of a new kind of iron by melting wrought iron and steel in crucibles, the above definitions were all that could be desired. At first, probably, owing to imperfect appliances, only a highly carburized iron was melted in crucibles, and this led to its being called *cast steel.* If our ancestors had found a name for this material not involving the use of the word steel, we would have been saved the trouble of the present discussion.

As the arts developed, new uses were found for steel, and the products of the crucible were varied, until at the present day it is quite common to find steel containing no more carbon than average wrought iron, and other steel containing nearly or quite as much carbon as some cast iron. All of these various products of the crucible have retained, or received, the name *cast steel,* usually abbreviated to the simple word steel, without causing any confusion among producers or consumers in regard to terms or their meaning.

In 1855, twenty-one years ago, the Bessemer process was introduced; this was followed in a few years by the Siemens-Martin process, and the products of both were at once, and have ever since been, called steel, from the fact that they were identical in chemical and physical properties with crucible cast steel.

At the present time, then, we have three subdivisions of cast steel, viz.: Crucible cast steel, Bessemer cast steel, and Siemens-Martin,

or open-hearth, cast steel. The enormous increase of the steel industry resulting from these three processes has brought steel fully up in importance to the rank of wrought iron and cast iron.

The original steel, commonly known and still sufficiently defined as blister steel, German steel, and shear steel, is becoming rapidly a thing of the past. It has no value now to the world, except as a useful auxiliary in the manufacture of fine steel. It is disappearing everywhere as an article of commerce, because its functions are performed much better in every way by cast steel. Even as an intermediate product in the manufacture of crucible steel, it has been discarded, almost entirely in Europe, very largely in England, and to some extent in America.

Such being the facts in regard to the gradual abandonment of old methods and the adoption of new and better processes, an effort was made by a few who were familiar with the subject to adapt to the word steel a definition better suited to its present application than that usually found in the books. Although the old definitions of the word attribute to steel properties which are common to all compounds of iron and carbon, and although they utterly fail to convey any idea of some of the most important properties of cast steel, the effort to adapt a new definition to a new order of things, so ably put forward by Mr. Holley, has been met by argument and ridicule to such an extent that I feel compelled to present you the views of a steel-maker before you reach a final conclusion as to what is the most proper nomenclature of iron.

We have been quite a century in growing into our present commercial nomenclature, and we need be in no violent hurry to introduce abrupt changes. We have been told that the application of the word steel, in such compound phrases as homogeneous steel, boiler steel, low steel, mild steel, machinery steel, etc., is an Americanism, and that the matter is much better understood abroad.

Having met a number of eminent mining, mechanical, and railroad engineers from abroad during the past summer, I have taken occasion to observe their language in regard to steel, and I have found, without exception, that they speak of steel as we do; talking familiarly of steel rails, steel tires, steel boilers, etc., as if they knew no other names for these articles, and yet their speech involvëd the whole range of carburization from less than .10 per cent. of carbon up to the maximum.

In the United States, a very large percentage of all the steel that is produced, except for rails, is ordered to be made so that it will

barely harden, and from that degree of carburization to steel softer than ordinary wrought iron. No one is deceived by the name steel as applied to these products; there is no confusion of ideas either in the minds of makers or workers of them; neither is there any confusion as to what is implied by the terms blister steel, shear steel, or German steel; everything in regard to the nomenclature of steel is entirely harmonious between the makers, the manipulators, and the users of it; and this nomenclature is the outgrowth of more than a century of use, and not of a few years, as has been stated in this discussion.

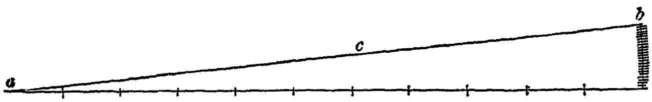
Now, if the few, the men of science, step in, and with the added weight of a very able international committee, say to us, "This is all wrong; you have no business with this word steel as you use it; the ancients said it meant so and so, and beyond this you have 'ingot iron' and not steel,"—what confusion it will work for us, and what trouble! Even if this change were possible and this new name was adopted, who would be benefited by it? Does it simplify matters to complicate them?

Having detained you so long in giving the reasons for disregarding the old definition of steel, and leaving out of consideration blister, German, and shear steels in forming a definition to suit the present condition of affairs, I will only add that I have dwelt upon this part of the subject at such length because the objection that the new definition leaves out the above steels is to my mind the only one yet made that is based on sound reasoning. Nevertheless, it is not insuperable, because the articles themselves have lost nearly all commercial and practical value; and as long as they have any existence at all, there is no more impropriety in calling them specific kinds of steel than there is in our every-day talk about lead-pencils, from which every trace of lead has long been removed.

In discussing the mechanical, structural, and chemical similarities and differences of the three general classes of iron, my remarks will apply to cast iron, wrought iron, and *cast* steel only. I will consider, first, the two most similar classes—cast iron and cast steel, and will regard them with reference to carbon and iron alone.

If a series of horizontal distances be allowed to represent well-defined grades of cast steel and cast iron, and a series of vertical distances to represent the percentages of carbon to iron in these various grades, the highest percentage of carbon known in cast iron being the point *b*, at a given distance above one end of the horizontal line,

other end of, and on the horizontal line at the point *a*,—or, more properly, let the point *a* represent pure iron,—then a straight line from *a* to *b* will contain the carbon points for every grade of cast iron and cast steel between the extremes given. We will call *a b* the *carbon line*, and *a c* the part of the line belonging to steel, and *b c* the portion belonging to cast iron. I propose now to show that in some respects there is a continuity of properties from *b* to *a*; in other respects a similarity of properties in the portions *b c* and *a c*; in still other respects an inversion of properties; and in others an entire difference. From this discussion I expect to deduce the conclusion that to cause any arbitrary break in either of these portions of the line, based upon the idea that at the point where the line was broken certain properties ceased to exist, would, in the present state of our knowledgé, simply be absurd.



1. In reference to structure, as it appears in the fractured ingot, or pig.

Beginning at *b*, we have a very coarse-grained, dark leaden-gray, and brightly lustrous fracture; as we move toward *c* the grain becomes finer, the leaden turns to iron-gray, and the lustre grows dim, until we have a fine-grained, lustreless gray iron. Farther down the line the grain assumes a mottled appearance and lighter color; then farther along, the mottled surface is interspersed with white spots, which gradually increase in size as we move along, until finally the surface is so nearly white as to contain only a few gray specks. These different fractures are known as coarse gray, gray, fine gray, mottled, mottled and white, white and mottled, and white iron. In dealing with cast iron of uniform character, I believe that differences of one-tenth of one per cent. of carbon can be observed with certain accuracy. Now, from white iron to white steel we have an unexplored region; but it is safe to assume that the change in structure from one to the other is so gradual that there is no exact point, *c*, of separation between cast iron and cast steel.

Beginning again at *c*, considered as the highest commercial steel, we have a bright silvery lustre, and an appearance of large crystals shaded alternately light and dark. The high steel and the high cast iron, speaking in a commercial sense, are very similar. As we go

down towards *a*, the lustre gradually disappears, the bright crystals separate, and amorphous gray spaces appear; the gray spaces grow larger and the crystals smaller, until we reach a fine gray, amorphous, lustreless grain; and finally, the grain grows larger, the color becomes darker, and the lustre more brilliant, until we reach a point where it is difficult to obtain a fracture. Differences of one-twentieth of one per cent. of carbon can be observed in steel with the utmost certainty.

In structure, then, we have an inversion of appearances, iron with the maximum amount of carbon resembling that with the minimum. Although the difference in appearance of any two similar grades as I have mentioned them, is such that steel could not be mistaken for cast iron, yet it would be very difficult to describe the difference in words so that the description would be a guide to a learner.

2. *Specific Gravity.*—Regard the whole series from *b* to *a* as having cooled from a state of fusion without interference; (or as iron and steel usually cool,) the specific gravity will increase regularly from *b* to *a*, the ordinary commercial extremes being about 7.14 to 7.855, and, as far as I have been able to compare given specific gravities with chemical analyses, there is no break in this line and there is no reason why there should be any deviation from it. In regard to hardness, however, there is no connection between this property and density. The extreme of hardness is somewhere about *c*, and the extreme of softness is at *a*, while cast iron also becomes softer as the carbon increases.

3. *Tensile Strength.*—The tensile strength of cast iron increases regularly from *b* up to where the specific gravity is from 7.3 to 7.33, and then decreases up to specific gravity 7.4, or to as high density as we have recorded.

The tensile strength of steel is at its maximum with about 0.9 per cent. of carbon, and falls nearly 25 per cent. when the carbon is increased to 1.2 per cent., and rather more than 40 per cent. when the carbon is reduced to 0.3 per cent., and becomes still less as the carbon is still further diminished in amount. Here, then, we have a similarity of properties in the two classes, cast iron and cast steel.

4. *Resistance to Compression.*

5. *Resilience.*

In reference to resistance to compression and resilience, the data in the case of cast iron are so incomplete and indefinite that I will not attempt a comparison.

6. *Hardening.*—It is recorded that cast iron of carbon 4.0281 per cent. has been hardened to a depth of one inch by pouring the iron, completely fused, into a thick cast-iron mould. It is also stated that very gray iron may be almost completely chilled by heating it very much hotter than its melting-point, and pouring it at that temperature into a strong cast-iron chill. This gives us the hardening temperature of *b*, at some unknown point above its temperature of fusion. If different lots of cast iron, varying in carbon from *b* to white iron, by regular differences, be melted and poured into chills of uniform size, the pieces, when cold, will be found to be harder and chilled deeper, each than the other, in regular order down the carbon line. Until recently I had supposed that no cast iron could be perfectly hardened so as to be entirely free from little specks of graphitic carbon; but I succeeded, by taking iron so white as to be itself almost free from graphitic spots, and pouring it, thoroughly melted, into a chill of small section, in chilling it so that no black spots were to be seen in the fracture. Hence the hardening temperature of white cast iron is the temperature of fusion. Passing now to steel, and beginning at *c*, we find that the highest steel may be hardened through quite uniformly at a moderate red heat.

As we pass down the carbon line, a higher heat is required for each successive piece of steel, in order to harden it through and refine it. Finally, we come to a point where a white heat is necessary, and beyond that the pieces remain soft in the centre, the soft centre increasing as we go down, until apparent hardening ceases at about 0.2 per cent. of carbon. Below this point, if we resort to fusion, we will find that upon being chilled the steel will take a crystallized form, strongly resembling the crystals in a cast-iron chill; and the farther we go down the line, the more decided this effect will become. But these crystals will not be hard, as they are in cast iron, owing to insufficiency of carbon; and this fact leads to the idea that the structure of a chill is due to iron rather than carbon, while the hardness is regulated by the carbon present.

From the point where ordinary hardening is plainly perceptible, down to the lowest attainable point in the carbon line, we have means of determining the effect of the hardening process, and so also approximately the quantity of carbon present. One very reliable test is by bending, similar to that used by the Neuburg blacksmith, referred to in one of the discussions of this subject, with this difference, however, that in very low steel the test has real value and is reliable, while in high steel the results obtained by the

blacksmith are simply worthless in comparison with the reliable results obtained in a different way by steel-makers. When the bending test ceases to be operative, cold forging serves a very good purpose, and lastly we try a welding test. When steel is so mild that it will not weld it may be whittled with a common penknife, and at this point practice ceases.

To what changes shall we attribute this hardening? Some say it is due to a chemical combination of iron and carbon. This is possible, but it is not yet fully proved. It has also been attributed to compression caused by sudden contraction. I think there are good reasons why this is not probable, if at all possible. A French writer has suggested that it is owing to a change in the carbon itself, from an amorphous to a crystalline state. I think this suggestion is well worth investigation.

7. *Tempering.*—The whole series from *a* to *b* presents exactly the same characteristics in tempering. Tempering is simply annealing slightly. Annealing is the softening of any piece under treatment by raising its temperature. For every increment of heat there is an increment of softness, up to the softness of liquidity. It has been offered as an argument that low steel is not steel; that such steel plunged at a red heat into cold water will not be hardened, but will be "water annealed."

There is no such thing as "water annealing;" it is a misnomer. If a piece of steel be heated to any temperature below its hardening temperature, it will be softened whether it be cooled slowly in dry ashes or rapidly in cold water; neither the ashes nor the water have anything to do with the annealing. The mode of cooling merely regulates the amount of annealing, or softness, that may be retained at the temperature known as cold.

If in the hardening of steel or of cast iron the two elements under consideration—iron and carbon—form definite compounds, and any one can tell us just where the formation of these compounds begins, and just where it ends; if we can be told, at this point you have hardening, and below this point you have no action, we will gladly drop the subject. Pleased at being so enlightened, we will accept the dictum of our instructors, and agree that up to such a point we have iron, from there we have steel to another fixed point, and from there we have cast iron. Until we are so informed we must be guided by what we know. We know that the effects of changes of temperature, whether sudden or gradual, are practically and accurately observable in every grade of cast iron or cast steel that is

known to commerce. The mercury in the themometer is not more sensitive to the action of heat than are homogeneous irons of any composition; neither does the mercury show any more clearly the warmth or coldness of the air than does the grain of any homogeneous iron indicate the amount of heat to which it has been subjected; and, farther, either the structure of any ingot of steel, or pig of iron, or the behavior of the bar of steel under treatment marks its proper place in the carbon line no matter where that place may be.

Therefore, we feel justified in calling everything in the line *a b* either cast steel or cast iron; and, reasoning from the facts given, does it not seem absurd to suppose that a certain action ceases at some unknown indeterminate point in this line, and yet that a century of observation and manipulation have failed utterly to disclose this remarkable break in the operation of a natural law? Does it not rather seem that such a conclusion is unscientific in the extreme? You would hardly say that salt water ceases to be salt to the tongue that cannot taste it. Neither would you insist that the earth does not revolve upon its axis because you cannot see it spinning around. Yet because a file, or a hammer, or some such sensitive instrument fails to reveal a perceptible degree of hardness in a piece of steel after it has been treated in a certain way, it is assumed that the action of the carbon in that piece of steel has ceased; and without presenting any reason why that action should have ceased and this wonderful law of change should have become inoperative, we are to agree that this thing has happened, because we cannot see in the ordinary way that it has not happened.

We can now examine this line *a b* and the two classes of iron it represents with reference: 1. To a continuity of properties. 2. To a similarity of properties. 3. To a difference of properties.

1. *Continuous Properties.*—The variations in total iron and total carbon are continuous throughout the line; the specific gravities vary with the carbon and iron, increasing all the way down, as the carbon diminishes. Expansion and contraction due to changes in temperature are continuous through the whole series.

2. *Similar Properties.*—Resistances to stress present similar variations in each series, in every kind of strain, as far as we have any information on the subject.

3. *Different Properties.*—There is the structural difference that the fracture at *b* resembles the fracture at *a*, and the fracture of the highest steel resembles the fracture of the cast iron lowest in carbon. Normally the hardness of steel increases with the carbon, while in

cast iron the hardness diminishes as the carbon increases. In the hardening property, the hardening temperature of steel increases as the carbon diminishes, while in cast iron the hardening temperature increases as the carbon increases. There is the important mechanical difference that cast steel can be forged, and cast iron cannot be forged. There appears to be a chemical difference, or perhaps more properly, a chemical distinction.

It would seem from the greater strength and ductility of steel, and also from the greater perfection of its hardening properties, that steel contains carbon within the limits of saturation, or within such limits that all of the carbon operates for the production of desirable effects, while cast iron contains carbon beyond this limit of saturation, or in such large quantities as to cause it to be non-forgable, brittle and lower in resistance to every stress than cast steel. The most remarkable fact in this connection is that this excess of carbon should not act continuously to increase brittleness and diminish strength. On the contrary, it has been shown that if the line *a b* were to be broken at *c*, and point *b* were to be placed below *a*, so that *a c* and *b c* should be parallel, and the lines of resistance to stress were to be laid off upon each line so as to show the differences due to variation in carbon, these lines would be nearly or quite parallel.

We come now to consider the third general class of iron—wrought iron. There is no question as to the proper relation of wrought iron to cast iron, and I will pass at once to the comparison of wrought iron and cast steel.

Wrought iron is generally conceded to be non-homogeneous; it has no serial conditions such as we have discussed in cast iron and cast steel, its quality depending upon its freedom from impurities and the perfection of its manipulation. Wrought iron is non-homogeneous because it consists of alternate layers of iron and cinder, and therefore its structure can never be similar to that structure of iron which has been produced by fusion, and which cannot be laminated.

In ductility and most physical properties there are strong resemblances between wrought iron and very mild cast steel, to which ample importance has been attached. It has been claimed that wrought iron and an ingot made from fused wrought iron are the same chemically, and it is very possible that a piece of wrought iron and a piece of cast steel might be found which, under analysis, would yield identical results in columns of percentages of carbon, silicon, phosphorus, etc.; but if the piece of wrought iron were to be thor-

oughly fused, a considerable amount of slag would rise to the surface of the molten metal; and by skimming off the slag and pouring the iron into a mould we would produce an ingot of cast steel. It is difficult to conceive how the ingot minus the slag could be chemically the same as the iron including the slag. In physical properties experience teaches us that the ingot will be more ductile, the bar made from it will be stronger, and in every way the cast steel will be superior to the iron from which it was made.

The limitation of the word steel to the products of the crucible is objected to because originally it applied only to a property of carbon and iron combined; now if the original limitation is to be adhered to, we may say cast iron is steel, because this property of hardening continues all through the cast iron series. If it is improper to change the definition of a word so as to adapt it to its largest use, is it not still more improper to introduce new names into important places when there is no reason for abandoning old names which are well understood and entirely explicit? The name *cast steel* belongs exclusively to the products of the crucible, the Bessemer converter, and the open hearth; and the only change necessary to make Mr. Holley's definition entirely unobjectionable, is to use in place of the word "steel," the compound descriptive word *cast steel*, which has been in use for more than a hundred years.

Those who object to any word which involves an allusion to a mode of manufacture, talk serenely about igneous rocks, metamorphic rocks, and sedimentary rocks, and rejoice in the beauty of a nomenclature which describes the thing and its mode of manufacture in one word. Nor have we heard any objection from this source to the similar name—"cast iron"—which is applied to the more highly carburized irons; and possibly the caricature from which "pig iron" derives its name has not presented any idea of inconsistency to their minds, or else they would not attempt to misapply the word "ingot" to an indeterminate portion of the steel series, inasmuch as it is derived from an intermediate condition of cast steel, which bears the same relation to cast steel that pig iron does to cast iron.

I appeal from the decision of the committee on nomenclature, and join those who object to changes and new names, which will cause confusion. Let us have the old names—cast iron, wrought iron, and cast steel. Define cast iron as iron which has been made homogeneous through fluidity, and which contains so much carbon that it cannot be forged; wrought iron as iron which is not homogeneous because it was not produced by fluidity, and which can be forged;

cast steel as iron which has been made homogeneous through fluidity, and which contains so little carbon that it may be forged.

This nomenclature and these definitions would be accepted by the world at large because the names are familiar household words, and the definitions are simple and easily to be understood; they would be acquired readily by the student, and would not present to his mind any confusing or startling ideas. As a crowning beauty to this nomenclature, lovers of deep and intricate argument would still have the simple word "steel" to ponder over, and the question "What is steel?" and the answer, "What steel is," would furnish food for discussion until the next Centennial; although in the meantime the toilers in iron might wag along in peace and harmony.

THE CHARACTER AND COMPOSITION OF THE LIGNITE COALS OF COLORADO.

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THERE is probably no more interesting group of mineral fuels to be found in any country than that occurring within the limits of the new State of Colorado. The supplies are so abundant, and the occurrence and distribution are so favorable for easy development and transportation to the future manufacturing centres of the State, that they are destined to play a very important part in the material growth and prosperity of the region, the more so because of the rich and varied stores of ores awaiting metallurgical treatment, and the comparative scarcity of timber for fuel.

From a purely scientific point, also, these lignitic coals form an interesting and important series. An examination of their geological occurrence and relations opens up new and important questions regarding the comparative value of various kinds of geological evidence, while a study of the character and composition of this class of fuels, which forms a connecting link, as it were, between the lignites and the true bituminous coals, may lead to a more thorough and accurate classification of mineral fuels.

The analyses here presented are from samples, of not less than fifty pounds each, obtained by myself during the summer of 1875, and may be regarded as representing very fairly the average run of

the coals mined. The largest part of the chemical work was done by my partner, Mr. George W. Riggs, Jr., Ph.B.

The analyses are arranged in the table according to the order of the geographical occurrence of the coals from north to south along the eastern slope of the Rocky Mountains, beginning with that mined at Erie, in the northern part of the State, and ending with the Trinidad coal of Southern Colorado, and some interesting graphitic lignites from the Raton Mountains, in the adjacent parts of Northern New Mexico. A semi-anthracite from the head-waters of the Gunnison River, across the Snowy Range, is inserted between the unaltered coals north of Trinidad and the highly metamorphosed series to the south, and for the sake of comparison, analyses of a semi-anthracite lignite, recently received from Peru, South America, are added.

No. 1. "Erie Coal" is from the Canfield Mines, worked by Canfield, Eaton & Co., about 1½ miles from the town of Erie, Boulder County, and 12 miles east from Boulder City, on the line of the Boulder Valley Railroad. The seam is 4′ to 4′ 6″ thick, and shows a slate parting about 10″ from the top. The coal is of jet-black color and streak, of rather dull lustre, and exhibits an imperfect laminated structure. It is hard and brittle, becomes tender by exposure to the air, and breaks up into irregular cuboidal fragments. When fired, it burns readily with a thin smoky flame, and crumbles easily. It yields a light pulverulent coke.

No. 2. Marshall Coal is mined on the east side of South Boulder Creek, about 5 miles southeast of Boulder City, and 4 miles west of Coal Creek Station, on the Golden and Julesburg Railroad.

The coal is 11′ to 14′ thick, but in mining 3′ to 4′ of top coal are left to give a better roof. It has a bright lustre on freshly fractured faces, and is of jet-black color and streak, of somewhat laminated structure, and breaks readily into irregular cuboidal fragments. It burns freely with slightly smoky flame, does not hold together in the fire, and yields a little pulverulent coke.

No. 3. "Black Diamond Coal" crops out ½ mile south of the Marshall Coal, and about 35′ above the latter. It is 8′ thick, and quite similar in appearance to the Marshall, but shows a more decided lamination. Yields coke only in powder.

No. 4. "Golden City, 12′ seam."

No. 5. "Golden City, 4′ seam."

No. 6. "Golden City, 6′ seam."

ANALYSES OF THE LIGNITE COALS OF COLORADO.

	No. 1. Erie.	No. 2. Marshall.	No. 3. Black Diamond	No. 4. Golden City (12 feet seam).	No 5. Golden City (4 feet seam).	No. 6 Golden City (6 foot seam).	No. 7. Mt Carbon.	No. 8. Lechner's South Park	No 9. Cañon City (vertical seam)	No 10. Cañon City (upper seam).	No. 11. Cañon City (lower seam).	No. 12 Walsenberg	No 13 Trinidad (coal)	No. 14 Trinidad (coke)	No 15 Semi-anthracite, Gunnison River.	No 16 Graphitic Anthracite (a, hard), Raton Mountains	No. 17 Graphitic Anthracite (b, soft), Raton Mountains	No. 18 Anthracite, Peru, S A.	Average of 1 to 13, inclusive.
Specific gravity	1.361	1 348	1 361	1 400	1 370	1.421	1.387	1 333	1.338	1 379	1 370	1 378	1 320	1 054	1 471	.	...	1 778	1 374
Moisture	18 570	13 190	14.670	17.640	17.150	18 350	20 380	6 302	7 007	6 565	7.665	3 650	1.150	1 540	1 500	1 220	1 190	11.150	11.713
Volatile	32 710	37 840	43 050	41 230	44 740	36 200	36 910	33 795	37 610	36.743	37 210	35 447	30 200	6 350	12 160	5 450	4 370	12 350	37 206
Fixed carbon	45.980	46.430	39 010	38 460	34 890	42 080	37 840	58 618	51 358	47 932	49 535	49 403	58 040	74 850	84 050	71 790	76 070	70 550	46 121
Ash	2.740	2 540	3 270	2.670	3 220	3 370	4.870	1 285	4 025	8 760	5 590	11 580	10 610	17 260	2 290	21.540	18 370	5 950	4 965
Sulphur	0 525	0.669	0 771	0.299	0.421	0.430	0 402	0 468	1.025	0 616	0 819	0 651	0 595	0.655	0.700	0.170	0.190	0.205	0 514
Iron	0 265	0.241	0 395	0 264	0.289	0 278	0.377	0 106	0 398	0 382	0 923	0 413	0 267	...	...	0 630	.	...	...
Sulphur required for $Fe S_2$	0 303	0 275	0.451	0.302	0 330	0 318	0.431	0 121	0.455	0 436	1 055	0 472	0 305	...	...	0 720	..		..
Sulphur (+ or —)	+.222	+.394	+.320	—003	+ 091	+.112	—029	+.347	+.570	+.180	—236	+ 179	+.290	.	..	—0 550	.	.	+0 187
Ash: Color	Light-yellow	Dirty-yellow	Yellow	Light-olive	Light-olive.	Dirty-yellow	Greenish-yellow.	Buff	Orange	Pink-gray.	Light-brown	Pink-gray.	Pink		..	..	..	..	.
Ash: Silica	28.600	10 440	13 400	13 430	10 780	5.300	37 500	43 470	30 960	39 780	44 140	68 070	65 700	...	..	..	.	.	.
Ash: Alumina	18 280	12 540	6 770	7 550	12 500	8 960	13 940	23 290	13 750	25 920	14 020	19 690	23 230	..	...	...	..	.	...
Ash: Lime	14.760	29 600	27.090	47 400	37 400	39.400	24 290	14.300	20 760	16 260	15 750	5 640	4 150	...	...	..	.		.
Ash: Peroxide of iron	13.820	13.630	17.280	14.150	12.860	11 800	11.060	11.800	14.130	6 240	23.620	5 900	5.460	...	...	...	...	...	...

ANALYSES OF THE LIGNITE COALS OF COLORADO—*Continued.*

	Moisture.	Carbon.		Hydrogen.		Oxygen.	Nitrogen.	Ash.	Sulphur.	Combined water.	Calorific Power I.	Approximate ratio in volatile matter of H and C.	Calorific Power II	Calorific Power compared with that of pure carbon.	Calorific intensity, Cent.
		Fixed.	Combined with hydrogen.	With carbon.	With oxygen										
No. 1. Erie	18 570	45 980	19 650	3 419	0 831	6.645	1.640	2.740	0.525	7.476	6121	1 . 6	6311	78 per cent	2572°
No. 2. Marshall	13 190	46.430	16 300	5 918	1 512	12 101	1.340	2 540	0 664	13.613	6510	1 . 3	6510	81 " "	2467°
No. 3. Black Diamond	14.670	39 010	22.050	3 795	1 665	13 319	1 450	3.276	0 771	14 984	5837	1 6	6057	75 " "	2555°
No. 4. Golden City (12 feet seam)	17 640	38 460	21.210	3 155	1 735	13.881	0 950	2 670	0 299	15 616	5526	1 : 6	5818	72 " "	2548°
No. 5. " " (4 feet seam)	17.150	34.890	23.080	3.315	1 825	14 599	1 500	3 220	0 421	16 421	5132	1 : 6	5769	71 " "	2568°
No. 6. " " (6 feet seam)	18 350	42.080	11 730	1 600	3.470	27.770	1 200	3.370	0 430	31.240	4530	1 6	4710	58 " "	2381°
No. 7. Mt. Carbon	20 380	37 820	23 670	4 075	0 835	6.678	1.250	4 870	0 402	7 513	5962	1 : 6	6198	77 " "	2576°
No. 8. Lechner's South Park	6.302	58 618	12 882	3 622	1 608	12.865	2 350	1 285	0 468	14 473	6780	1 · 3	6780	84 " "	2545°
No. 9. Cañon City (vertical seam)	7 007	51 358	18.432	6 221	1.159	9 273	1 500	4.025	1.025	10 432	7276	1 : 3	7276	90 " "	2561°
No 10. " " (upper seam)	6 565	47 932	16 868	3 853	1.517	12 139	1 750	8 760	0 616	13 656	6206	1 6	6221	77 " "	2540°
No. 11. " " (lower seam)	7.665	49.535	18 175	3.957	1.423	11 386	1 450	5 590	0 819	12.809	6469	1 : 6	6517	81 " "	2559°
No. 12. Walsenberg	3 650	49 403	11.557	3 377	2 083	16 669	1 030	11 580	0.651	18 752	5822	1 · 3	5822	72 " "	2543°
No. 13. Trinidad	1.150	58.040	18.760	6 501	0 299	2.395	1.650	10 610	0 595	2.694	7969	1 : 3	7969	99 " "	2647°
No. 15. Semi-anthracite, Gunnison River	1.500	84 050	0.920	3 190	0.530	4.200	1 620	2 290	0.700	4 730	7911	3 : 1	7911	98 " "	2634°
No. 18. Anthracite, Peru, S. A.	11.150	70.550	4 050	1 884	0 646	5.169	0.396	5 950	0 205	5.815	6384	1 : 3	6384	79 " "	2581°
No. 16. Graphitic Anthracite (*a*, hard), Raton Mountains	1.220	71.790	2.360	0.924	0 206	1 648	0 142	21.540	0.170	1.854	……	… …..	. .	. . …. .	. …
Average of 1 to 13, inclusive	11 713	46 125	18.028	39.080	1 535	12 286	1 466	4.640	0 514	13 821	6188	. . .	6304	78 per cent.	2543°

These seams are worked by the Golden City Land and Coal Co. They stand nearly vertical, and are separated by intervening beds of fire-clay or sandstone, from 2′ to 8′ in thickness. The coal from all these seams is jet-black in color and streak, with dull lustre, especially marked in No. 5. Beyond the frequent occurrence of slickensides, the structure of these coals does not exhibit any evidence of the pressure to which they were subjected during the elevation of the strata. They break easily in any direction, and after being exposed to the air for a time fall away to small irregular fragments. They burn freely with almost smokeless flame, and fall away to powder. When heated in a closed vessel they give off the volatile matter without changing form.

No. 7. "Mount Carbon coal" is from a nearly vertical seam, 2′ .6″ to 5′ .6″ thick, worked by Hodgson & Eaton, on the line of the Denver and South Park Railroad, about two miles east of Morrison, and 16 west of Denver. The coal is of dull lustre, smooth and even texture, without lamination or cleavage, and clean to the touch. On exposure it cracks, and finally falls away to fine coal. It slacks readily when heated, and yields no coke.

No. 8, "Lechner coal," worked by Mr. Geo. W. Lechner, 1½ miles from Hamilton, and 8 miles northeast of Fairplay, in the South Park. The seam is about 12′ thick and the coal is of rather dull lustre, uneven fracture, and without lamination. It is of jet-black color and streak, and exhibits a tendency to slack when exposed to the air and when heated. It burns freely without changing form and yields no coke.

No. 9, Cañon City, vertical seam.

No. 10, Cañon City, upper seam.

No. 11, Cañon City, lower seam.

No. 9 is from one of the small and nearly vertical seams cropping out at the base of the foot-hills along Mill Creek, about 3 miles south of Cañon City. The coal is 3′ thick, of bright pitchy lustre on freshly fractured surfaces, and of jet-black color and streak. It is hard, brittle, and breaks easily in any direction, but does not slack on exposure as readily as the coals already described. It yields a very weak sandy coke.

Nos. 10 and 11 are coals mined by the Denver and Rio Grande Railroad Company, at Coal Creek on the south side of the Arkansas River, and about 6 miles southeast from Cañon City. The upper seam, about 4′ thick, is not worked at present, but the lower seam, known generally as the "Cañon City coal," has been mined more exten-

sively than any other in Colorado. The latter averages 5′ in thickness, and bears a strong resemblance to true bituminous coal. It has a well-marked vertical cleavage in two directions, and breaks in cuboidal blocks, but does not slack as readily as the coals further north. It is of jet-black color and streak, bright lustre, and laminated structure. Thin seams of calcite are of frequent occurrence on the cleavage-planes. Both coals burn with a bright, somewhat smoky flame, swell slightly, but show a tendency to fall to powder when first heated. Both yield a weak coke.

No. 12, "Walsenberg coal," has been mined to some extent at the town of Walsenberg, county seat of Huerfano County, about 50 miles south of Pueblo. The seam is 8′ 6″ thick, and the coal is of a dull lustre, with occasional bright pitch-like layers, and resembles the splint coals somewhat in appearance. It is of jet-black color and streak, shows two well-marked vertical cleavage-planes, is stronger than most of the other Colorado lignite coals, and is less affected by exposure to the weather. In burning it slacks somewhat, swells, and cakes a little. It yields a weak coke.

No. 13, "Trinidad coal," is from the mines of the Raton Coal and Coke Company, of Trinidad, Los Animas County. The seam is from 9′ to 10′ thick, and the coal is to all appearances true bituminous coal, resembling very much the black coal of Ohio. The color is jet-black, but the powder and streak dark-brown. The small irregular cracks so generally developed in lignite coals on exposure scarcely appear in the Trinidad coal, and the tendency to slack is not much greater than in many of the true bituminous coals. This is the only lignite coal so far examined which swells and cakes decidedly in burning. It yields an excellent coke, which will compare favorably with that made from many of the carboniferous coals.

No. 14, "Trinidad coke," made from the above coal in open heaps by the Trinidad Coal and Coke Co. It is a strong cellular coke, of steel-gray color, containing some fragments of slate.

No. 15, Semi-anthracite, from the head-waters of the Gunnison River. It is quite hard and brittle, has a bright lustre and subconchoidal fracture, and resembles some of the anthracite coals of South Wales more than those of Pennsylvania. The analyses were made from a sample brought over the range by a prospector, and is probably the same coal referred to in Dr. Hayden's report for 1873.

Nos. 16 and 17, graphitic lignites, from the Raton Mountains, about 40 miles southwest from Trinidad. The samples were taken from a seam of impure lignitic coal which had been metamorphosed

by an intrusive trap. No. 16 is hard, and resembles some of the graphitic anthracites of Rhode Island. No. 17 is soft and graphitic. The analyses are given for the purpose of comparing graphitic lignite with the graphites of the older rocks. Unfortunately, samples of the unaltered lignite coal from this seam could not be obtained.

No. 18, Semi-anthracite lignite from the line of the Chimbote and Hauraz Railroad, in Peru, South America. The analyses were made from a sample brought to this country by Mr. Gillespie, an American engineer connected with the above-named railroad. This is an exceedingly beautiful coal of very brilliant lustre and steel-gray color. It has a strong cleavage in two directions, and exhibits a concretionary structure similar to some of the hard anthracites of Pennsylvania. It resembles very much the beautiful anthracite lignite of Queen Charlotte's Island on the Pacific coast. The analyses are submitted for the sake of comparison. Although it has the hardness and lustre of anthracite, its composition is that of semi-anthracite.

It will be seen from the above general description of the coals whose analyses are given, that they cannot, with propriety, be classed with the lignites proper. None of them show anything like a ligneous structure, or bear much resemblance to the so-called brown coals of Europe, as far as structure is concerned. They resemble rather the true bituminous coals in appearance, having the characteristic jet-black color and streak, compact or laminated structure, and generally high pitchy lustre. The Trinidad is the only one which has a brown powder and streak, and it is the one which bears the closest resemblance in other respects to the carboniferous coals.

In the chemical composition the lignitic character of these coals becomes more apparent. The amount of moisture (averaging 11.713 per cent.) and chemically combined water (13.821 per cent.) is much larger, and the amount of fixed carbon (46.121 per cent.) somewhat less than in the average carboniferous coals, and their behavior when fired is quite different. They occupy a position between the true lignites and the true bituminous coals, partaking in some degree of the peculiarities of both extremes. The term lignite coal or lignitic coal seems, therefore, the most appropriate one for this class of mineral fuels.

A glance at the table of ultimate analyses, will show that the geographical order in which the coals are there arranged is, in the main, the inverse order of their metallurgical value; that is, with few exceptions, the coals seem to improve in quality from north to

south. In the coals north of Cañon City and Lechner's, the percentage of moisture is very much greater than in those to the south. Nos. 15, 16, and 18 are not taken into consideration, as they are more or less metamorphosed. The conditions under which the moisture was determined in all these coals were quite similar, and such as to give a fair idea of the relative proportions of hygroscopic water contained in them when air-dried in their natural state. The coals were all exposed in open boxes in a dry room for about three months before the samples were taken for analysis.

The percentage of fixed carbon is notably higher in the southern coals, and the average percentage of available hydrogen is also greater in these. There is much less oxygen, too, in the southern coals than in the northern, the notable exceptions being the "Erie" and "Mt. Carbon," which are quite low in oxygen for the northern, and the "Walsenberg," which is rather high in the same element, for the southern series.

In the amount of ash these coals offer something of a contrast to the typical lignites or brown coals. With the exception of the "Trinidad," "Walsenberg," and "Upper Cañon City," the percentage of ash is remarkably small, averaging only 3.358 per cent. The southern coals contain considerably more ash than those of the north, and in the composition of the ash there is a remarkably uniform difference in the two series. The coals to the north show a comparatively small amount of silica and alumina, and a large amount of lime in the ash, and these resemble the true lignites or brown coals, while those to the south have higher percentages of silica and alumina, and less lime, which is more characteristic of the true bituminous coals.

It would appear, then, from an examination of these coals (Nos. 1 to 13), which are at present the most important in the State, that as a general rule those coals occurring in the northern half of the State, on the eastern slope of the Rocky Mountains, are more lignitic in character than those of the southern half, and in the following respects:

I. They slack more readily when exposed to the weather and in burning.

II. In containing a larger percentage of hygroscopic water.

III. In the larger amount of oxygen, and consequently greater yield of combined water.

IV. In having less fixed carbon.

V. In the smaller proportion of available hydrogen.

VI. In the composition of the ash, less silica and alumina, and more lime.

The more lignitic character of the northern coals, and the greater resemblance to the true bituminous in the coals of the southern part of the State, point to the greater age of the latter—a conclusion for the support of which stratigraphical evidence is not wanting.

The Trinidad coal (No. 13) proves on analysis, as it has been proved in practice, to be the best of the Colorado fuels. In fact it is difficult to see why it should not be classed—judging from its composition and physical properties—with the true bituminous coals.

The semi-anthracite from the Gunnison River (No. 15) resembles in composition the semi-anthracite resulting from the metamorphism of carboniferous coals, and exhibits no lignitic peculiarities.

The semi-anthracite from Peru (No. 18) is much more lignitic in character. The amount of moisture (11.15 per cent.) and of combined water (5.815 per cent.) being much higher than results from carboniferous coals metamorphosed to the same degree. The specific gravity of this coal is remarkably high, considering its percentage of ash.

The graphitic anthracite (No. 16) also shows lignitic tendencies, notwithstanding the great degree of metamorphism to which it has been subjected.

In connection with the sulphur determinations, estimates are given in the table of the amount of sulphur required to form iron pyrites, with the iron found in each case. It will be seen that in ten of the thirteen unaltered lignite coals there is considerable sulphur in excess, the average for the whole thirteen being 0.187 per cent. in excess. In the graphitic anthracite (No. 14) there is, as might have been expected, a deficiency in sulphur.

The calorific powers of these fuels have been calculated upon two different hypotheses, and the results are given in the columns marked I and II.

The error in calculating the calorific power of a fuel, on the supposition that all the carbon and available hydrogen are burned as free carbon and hydrogen, has been pointed out by Mr. Marvine in his report to Dr. Hayden for 1873. The available hydrogen is in combination with a certain portion of the carbon forming the hydrocarbons of the volatile combustible matter. In the combustion of these hydrocarbons, the carbon and hydrogen are separated from one another to unite with oxygen, and in this operation heat would be absorbed. The calorific modulus of the hydrocarbon must be used,

therefore, instead of taking the sum of the calorific moduli of the carbon and hydrogen. The question then arises, which of the hydrocarbons will be found in the volatile combustible matter of a coal undergoing combustion, the light hydrocarbon (marsh gas) with its calorific modulus of 13,063, or the heavy hydrocarbon (olefiant gas) with its calorific modulus of 11,858? Mr. Marvine, in his discussion of the calorific powers of Western lignite coals, assumed that the available hydrogen is always combined with carbon in the form of marsh gas. But his calculations were based upon ultimate analyses only, so that the amount of carbon combined with hydrogen in the volatile combustible matter could not be known.

An examination of the analyses submitted will show that in some cases the proportion of hydrogen to carbon is as 3 to 1, which is the proportion for marsh gas. In eight out of the fifteen, however, the proportion is 6 to 1, or that of olefiant gas. The first two coals illustrate this point very well. The "Erie" coal has 19.65 per cent. of carbon to combine with the 3.419 per cent. of available hydrogen (approximately 6 to 1), while the "Marshall" has 16 30 per cent. of carbon to combine with 5.918 per cent. of hydrogen (approximately 3 to 1).

The relation of the hydrogen to the carbon in the volatile matter of these coals approximates so closely to the ratios 3 to 1 and 6 to 1 as to indicate that the volatile matter given off, at least under the conditions which obtain in the analysis, is either marsh gas or olefiant gas. The extent to which the olefiant gas may suffer decomposition, with the formation of free carbon and marsh gas, when a coal undergoes combustion, varies with the conditions of combustion. In the calculation of theoretical calorific powers, however, it may be assumed that the combustion of the olefiant gas, as such, is perfect, and where analysis indicates the volatile combustible matter to be olefiant gas, the calorific modulus for that gas (11,858) is used.

In the column "Calorific Power I" will be found the calorific powers calculated on the supposition that the hydrogen is combined with only sufficient carbon to form marsh gas, the excess of carbon being added to the fixed carbon, where the ratio is 6 to 1. This series is introduced for the sake of comparison.

Column II gives the corrected calorific powers for the coals, in which the volatile matter consists of olefiant gas. The percentage values of calorific powers compared with that of pure carbon are given, also the calorific intensities calculated from the calorific powers given in column II.

Attention may be called to the analyses of the Lechner, Cañon City, and Walsenberg coals, as illustrating the importance of the ultimate analysis in determining the character and usefulness of a coal. From the proximate analysis they seem to be excellent true bituminous coals, the amount of moisture being not greater than that in many carboniferous coals of good quality. The ultimate analyses, however, show the volatile matter to be largely composed of combined water. The importance of having proximate as well as ultimate analyses has already been indicated in considering the character of the volatile combustible matter of these coals.

THE COAL PRODUCTION OF THE UNITED STATES.

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THOUGH coal has been mined in this country for more than a century, no systematic effort was ever successfully made to ascertain the total amount produced. The production of the Cumberland Basin, Md., and the shipments from the anthracite fields of Pennsylvania, have been placed upon record, thanks to the intelligence and foresight of Mr. C. Slack in the former case, and to the late Mr. B. Bannan in the latter. For some of the years between 1822 and 1842, the production of the Richmond Basin was reported by Mr. R. C. Taylor, but since that date till the author undertook this work it was impossible to obtain any statement of the production of this field. A few of the newer fields, such as that of Mt. Diablo, Cal., have been fully reported, and a few of the newer States have also had this service performed by some intelligent private individuals; but no statistics of coal production have ever been collected either by the State or General Government, if we except the returns for the years 1869–70 of the census report. During the year 1875, by great exertions, I succeeded in obtaining, and July 3d, 1875, gave in the *Engineering and Mining Journal* what, "though not an accurate statement of our coal production," was "by far the most full and reliable that had ever been published." Though that report showed the production of bituminous coal to be 23,630,094 gross tons, or about six million tons more than had ever before been reported, it was in reality two and a half million tons below the actual output. The more full returns I obtained for 1875 gave many figures for 1874

which I had been unable to obtain for the former report. The corrected returns for 1874 and 1875, which I give herewith, though not absolutely correct, are probably safely within five per cent. of the total production of bituminous coal; and as the reports of anthracite are full and accurate, the total will not be in error more than 2½ per cent. of the whole production of the country, and possibly it comes much nearer than this.

COAL PRODUCTION OF THE UNITED STATES—IN TONS OF 2240 POUNDS.

STATES.	Census Report June 1st, 1870.	Years ending Dec. 31st, 1874.	Years ending Dec. 31st, 1875.	Percentage of each State's production of the whole. 1875.
Alabama, bituminous	9,821	45,000	60,000	0 13
Arkansas, "	..	5,000	9 000	0 02
California, post-carboniferous coal	. .	214,600	166,100	0 35
Colorado, " " "	4,018	150,000	150,000	0 32
Illinois, bituminous	2,343,003	3,000,000	3,500,000	7 37
Indiana, "	390,955	812,000	800,000	1 69
Iowa, "	235,256	1,500,000	1,500,000	3 16
Kansas, "	29,410	250,000	275,000	0 58
Kentucky, "	134,449	360,000	375 000	0 79
Maryland, "	1,624,843	2,410,895	2,342 773	4 94
Michigan, "	25,134	12,000	12,000	0 02
Missouri, "	555 295	714,000	730,000	1 58
Nebraska, "	1,272	1,300	1,300	..
Nevada, post-carboniferous coal	. .	1,000	1,000	. .
Ohio, bituminous	2,256,504	3,810,344	4,346,653	9.15
Oregon, post-carboniferous coal	. ..	43,200	28,800	0 06
Pennsylvania, anthracite* and bituminous†	20,936,422	32,667,386	3 ,143 509	65 54
Rhode Island, anthracite	12,500	17,000	11 000	0 02
Tennessee, bituminous	119,123	350,000	360,000	0 76
Utah, post-carboniferous coal	5,178	30,000	35,000	0 07
Virginia, " " "	53,181	73,100	79,200	0 17
Washington, " " "	15,932	27,100	88 900	0 16
West Virginia, bituminous	543,641	1,000,000	1,100,000	2 32
Wyoming, post-carboniferous coal	44,643	260,000	278,000	0 59
N. Carolina, Georgia, and Indian Ter., bitum.	..	60,000	100,000	0 21
Total anthracite	13,985,960	21,684,386	20,654,509	43 48
Total bituminous	15,231,668	25,330,539	26,031,726	54 78
Total post-carboniferous coal	124,952	799,000	827,000	1 74
Total of all kinds	29,342,580	47,813,925	47,513,235	100 00
* Anthracite	13,973 460	1,667,386	20,643,509	43 41
† Bituminous	6,962,962	1,000,000	10,500,000	22.10

It is impossible, at this early date, to estimate with any degree of accuracy the production of each State in 1876. My reports indicate great changes, some States having considerably increased their output; others—such as Ohio and Maryland—having largely decreased it. The total production in 1876 was less than in 1875, and the deficiency may amount to two million tons, which would make it 45½ million gross tons; but these figures are subject to changes which even the numerous reports already received do not enable me to estimate.

The Production of Anthracite in Pennsylvania.—It will be interesting to note the production of Pennsylvania anthracite from year

to year since the opening of this trade. Without entering into the early history of anthracite coal mining, which would exceed the space allowed me, the above tabular statement will show the marvellously rapid and enormous development which this industry has undergone. My estimates for the production previous to 1820 are based upon the early records of the different fields, as contained in a great number of works, among which is a report of S. J. Packer, Chairman of a Committee of the Senate of Pennsylvania in 1834; Col. H. B. Wright's *Historical Sketches of Plymouth, Pa.*, in which some interesting original documents relating to the coal trade are quoted; an interesting paper by W. J. Buck, Curator of Records, Pennsylvania Historical Society, in which several of the old Pennsylvania manuscripts are quoted; the valuable work of the late R. C. Taylor on *Coal Statistics*, and that of Benjamin Bannan, on *Coal, Iron, and Oil;* the history and early reports of the Lehigh Coal and Navigation Company, and many other books and pamphlets.

The use of anthracite coal commenced in the Wyoming Valley as early as 1768, and in the Schuylkill and Lehigh regions about the year 1800. The total production from these dates to 1820 can only be estimated.

The production from 1820 to 1833, inclusive, is based, as to shipments, on the published reports of the transportation companies, and, as to consumption at the mines on the data collected by Mr. Packer's committee in 1834, and other contemporary records.

My estimates for *shipments* from 1834 to 1863, inclusive, are those published by the late Mr. Bannan (after making correction of several clerical errors) and by R. C. Taylor, and are based on the published returns of the transportation companies. My estimates of "consumption and sales at the mines" during those years are based upon the proportions given by Mr. Packer in 1834, and by Mr. Bannan at later dates, of the "shipments" and "home consumption." Mr. Bannan mentions the fact that previous to 1864 he did not include the "home consumption" in his statistical reports, and he entitles his tables throughout as "shipments" only. I have endeavored to supply this omission from the best obtainable data, and to give, consequently, the total production of coal.

From 1864 to 1873, inclusive, I have adopted Mr. Bannan's figures (after correction of clerical errors) for both shipments and home consumption. The proportion the latter bears to the former was arbitrarily fixed by Mr. Bannan upon data not given, and I find in fact that it varies considerably: from 1864 to 1868, inclusive, it was

The Anthracite Coal Production of Pennsylvania—in Tons of 2240 Pounds.

Years.	The Wyoming Region. Luzerne County.			The Lehigh Region. Carbon, Columbia, and Luzerne Counties.			The Schuylkill Region. Schuylkill, Northumberland, Columbia, Dauphin, and Lebanon Counties			Loyalsock Region Sullivan Co	All the Regions.					Years.
											Total.			Increase or decrease		
	Shipments.	Consumption and sales at mines.	Production.	Shipments.	Consumption and sales at mines.	Production.	Shipments.	Consumption and sales at mines.	Production.	Production, including 5 per ct consumption at mines.	Shipments to tide	Consumption and sales at mines.	Production.	Amounts	Per cent.	
Before 1820	....	10,000	10,000	....	3,000	3,000	....	5,000	5,000	....	....	18,000	18,000	....	....	Before 1820
1820	....	800	800	365	300	665	....	500	500	....	365	1,600	1,965	....	....	1820
1821	....	1,000	1,000	1,073	400	1,473	....	800	800	....	1,073	2,200	3,273	1,308	66 7	1821
1822	....	1,200	1,200	2,240	500	2,740	....	1,000	1,000	....	2,240	2 700	4,940	1,667	50 9	1822
1823	....	1,300	1,300	5,823	700	6,523	....	1,200	1,200	....	5 823	3,200	9,023	4,083	82 6	1823
1824	....	1,700	1,700	9,541	900	10,441	....	1,500	1,500	....	9,541	4,100	13,641	4,618	51 2	1824
1825	....	2,000	2,000	28,393	1,100	29,493	5,306	1,700	7 006	....	33,699	4,800	38,499	24,858	182 2	1825
1826	....	2,700	2,700	31,280	1,500	32,780	16,835	2,500	19,335	....	48,115	6,700	54,815	16,316	42 4	1826
1827	....	4,000	4,000	32,074	2,200	34 274	29,491	3,400	32,893	....	61,567	9 600	71,167	16,352	29 8	1827
1828	....	6,200	6,200	30,233	3,000	33,233	47,181	5,300	52,481	....	77 414	14,500	91,914	20,747	29 2	1828
1829	7,000	9,800	16,800	25,110	4,000	29,110	78,293	9 000	87,293	....	110,403	22,800	133,203	41,289	44 9	1829
1830	42,000	16,200	58 200	41,750	5,100	46 850	89,984	14,600	104,584	....	173,734	35,900	209,634	76,431	57 4	1830
1831	54,000	24,300	78,300	40,966	6,200	47,166	81,854	23 000	104,854	....	176,820	53,500	230,320	20,686	9 9	1831
1832	84,500	37,200	121,700	75,000	7,700	82,700	209,271	34 500	243,771	....	368,771	79,400	448,171	217,851	94 6	1832
1833	111,777	50,000	161,777	123 000	9,100	132 100	250,588	47,745	298,333	....	485,365	106 845	592,210	144,039	32 1	1833
1834	43,700	9,308	53,008	106,244	22,630	128,874	226,692	48,285	274 977	....	376,636	80,223	456,879	d 135,851	d 22 9	1834
1835	90,000	18,900	108,900	131,250	27,562	158,812	339,508	71 297	410,805	....	560,758	117,759	678,517	221,658	48 5	1835
1836	103,861	21 499	125,360	148,211	30,680	178 891	432,045	89,433	521,478	....	684,117	141,612	825,729	147,212	21 7	1836
1837	115,387	23 654	139,041	223,902	45,900	269,802	523,152	107,246	630 398	....	862,441	176,800	1,039,241	213,512	25 9	1837
1838	78,207	15,876	94,083	213,615	43,364	256 979	433 875	88,076	521,951	....	725,697	147,316	873,013	d 166,228	d 16 0	1838
1839	122,300	24,460	146,760	221 025	44,205	265 230	454 538	90,908	545,446	....	797,863	159 573	957,436	84 423	9 7	1839
1840	148,470	29,397	177,867	225,318	44,614	269,932	467,796	92 625	560 421	....	841,584	166,636	1,008,220	50,784	5 3	1840
1841	192,270	37,685	229,955	143,037	28,035	171,072	607,005	118,973	725,978	....	942,312	184,693	1,127,005	118,785	11 8	1841
1842	252,599	49,257	301,856	272,546	53,146	325,692	551,504	107,543	659,047	....	1,076,649	209,946	1,286 595	159 590	14 2	1842
1843	285,605	54,836	340,441	267 793	51,416	319,209	687,312	131,964	819,276	....	1,240,710	238,216	1,478,926	192 331	14 9	1843
1844	365,911	69,523	435 434	377,002	71,631	448,633	853,465	162,158	1,015,623	....	1 596,378	303,312	1,899,690	420,764	28 5	1844
1845	451,836	84,493	536,329	429,453	80 308	509,761	1,093,796	204,540	1,298,336	....	1,975,085	369,341	2,344 426	444,736	23 4	1845
1846	518,389	95,902	614 291	517,116	95,667	612,783	1,249,154	231,093	1,480,247	....	2,284 659	422,662	2,707,321	362,895	15 5	1846
1847	583,067	106,118	689,185	633 507	115,298	748 805	1,598,278	290,887	1,889,165	....	2,814,852	512,303	3 327,155	619,834	22 9	1847
1848	685,196	123,335	808,531	670,321	120,658	790,979	1,672,191	300,994	1,973,185	....	3,027,708	544,987	3,572 695	245,540	7 9	1848
1849	732,910	129,725	862,635	781,656	138,353	920,009	1,650,101	292,067	1,942,163	....	3,164,667	560,145	3,724,812	152,117	4 3	1849

1850	827 823	144,869	972,692	690,456	120 830	811,286	1,769,691	309,696	2,079,387	....	3,287,970	575,395	3,863,365	138,553	3 7	1850
1851	1,156,167	198,861	1,355,028	964,224	165,847	1,130,071	2,308,525	397,066	2,705,591	... .	4,428,916	761,774	5,190,690	1,327,325	34 4	1851
1852	1,284,500	218,365	1,502,865	1,072,136	182,263	1,254,399	2 536,653	431 231	2,967,884	....	4,893,289	831,879	5,725,148	534,458	12.1	1852
1853	1,475,732	247,923	1,723,655	1,054,309	177,124	1,231,433	2,555,450	429,315	2,984,765	. .. .	5,085,491	854,362	5,939,853	214,705	3 7	1853
1854	1,603,478	264,574	1,868 052	1,207,186	199,186	1,406,372	3,066,208	505,924	3,572,132	. ...	5,876,872	969,684	6,846,556	906,703	15 3	1854
1855	1,771,511	288,756	2,060,207	1,284,113	209,310	1,493,423	3,551,893	578,959	4,130,852	. . .. .	6,607,517	1,077,025	7,684,542	837,986	12 2	1855
1856	1,972,581	315,613	2,288,194	1,351 970	216,315	1 568,285	3,571,800	571,488	4,143,288	....	6,896,351	1,103,416	7,999 767	315,225	4 1	1856
1857	1,952,603	308,511	2,201,114	1,318 511	208,330	1,526 871	3,373,797	533,060	3,906,857	....	6,644,941	1,049,901	7,694,842	*d* 304,925	*d* 3 8	1857
1858	2,186,094	341,031	2,527,125	1 380,030	215,285	1,595,315	3,236,843	504,947	3,741,790	....	6,802 967	1,061,263	7,864,230	169,388	2 2	1858
1859	2,731,236	420 610	3,151,846	1,628,311	250,760	1,879,071	3,448,708	531,101	3,979,809	... .	7,808,255	1,202,471	9,010,726	1,146,496	14 6	1859
1860	2,941,817	447,156	3 388,973	1,821 674	276,895	2,098,569	3,749,632	569,944	4 319,576	....	8,513,123	1,293 995	9,807,118	796,392	8 8	1860
1861	3,055,140	458,271	3,513,411	1,738,377	260,757	1,999,134	3,160,797	474,119	3,634,916	....	7,954,314	1,193,147	9,147,461	*d* 659,657	*d* 6 7	1861
1862	3,145,770	462,428	3,608,198	1,351,054	198,604	1,549,658	3,432,584	504,591	3,937,175	. ... ..	7,929,408	1,165,623	9,095,031	*d* 52,430	*d* 0 6	1862
1863	3 759,610	545,144	4,304,754	1,894,713	274,733	2,169,446	3,911,683	567,194	4 478,877	....	9 566,006	1,387,071	10,953,077	1,858,046	20 4	1863
1864	3,960,836	565,799	4,526,635	2,054,669	293,364	2,348,233	4,161,970	594,562	4,756,532	....	10,177,475	1,453,925	11,631,400	678,323	6 2	1864
1865	3,255,658	465,059	3,720,717	1,822,535	260,323	2,082,858	4,356,959	622,498	4,979,457	....	9,435 152	1,347,880	10,783,032	*d* 848,368	*d* 7 3	1865
1866	4,736,616	677,342	5,413 958	2,128,867	304,413	2,433,280	5,464,269	781 390	6,245 599	....	12 329,692	1,763,145	14,092 837	3,309,805	30 7	1866
1867	5,328,322	760,950	6,089,272	2,062,446	294,421	2,356 867	5,161,671	737,834	5,899,505	.. ... .	12,552,439	1,793,205	14,345,644	252,807	1 8	1867
1868	5,990 813	855,886	6,846,699	2 507,582	358,238	2,865 820	5,335,737	762,210	6,097,947	....	13,834,132	1,976,334	15,810,466	1,464,822	10 2	1868
1869	6 068,369	1,211,174	7,279,543	1,929,523	384,466	2,313,989	5,653,855	1,128,291	6,782,146	.. .. ..	13,651,747	2,723,931	16,375,678	565,212	3 6	1869
1870	7,554,919	1,259,115	8,814,024	2,990,878	498,486	3,489,364	4,728 242	788,070	5,516,312	....	15,274,029	2,545,671	17,819,700	1,441,022	8 8	1870
1871	6,713,773	953,356	7,667,129	2,249,356	319,408	2,568,764	6,234,974	885,366	7,120,340	23,122	15,220,125	2,159,230	17,379,355	*d* 440,315	*d* 2 5	1871
1872	9,191,171	1,507,352	10,698,523	3,610 674	592,150	4,202,824	6,126,468	1,004,741	7,131,209	51,527	18,977,390	3,106,693	22,084,083	4,704,728	27.1	1872
1873	10,047,241	1,603,842	11,711,083	3,263,168	538,279	3,801,447	6,294,454	1,040,879	7,335,333	33,058	9,636,351	3,244,570	22,880,921	796 838	3 6	1873
1874	9,513,042	691,722	10,204,764	3,868,749	270,812	4,1 9,561	6,810,087	476,706	7,286,793	36,2 8	20,225,774	1,441,612	21,667,386	*d* 1,213,535	*d* 5 3	1874
1875	10,519,398	526,000	11,045,998	2 731,311	136,565	2,867,876	6,393,441	319,672	6,713 113	16,522	19,660,486	983,023	20 643,509	*d* 1,023,877	*d* 4 7	1875
1876*	8,100,000	400,000	8,500,000	3,800,000	170,000	3,970,000	6,200,000	300,000	6,500,000	30,000	18,130,000	870,000	19,000,000	*d* 1,643,509	*d* 8 6	1876
Total	125,913,797	17,262,077	143,175,872	59,585,696	8,436,531	68,022,227	130,245,548	18,930,688	149,176,236	190,497	315,927,258	44,637,574	360,564,832	....	....	... .

* Figures of production for 1876 are merely approximate, the returns not yet being revised.

14.3 per cent., in 1869 it was 19.9 per cent., in 1870 it was 16.6 per cent., in 1871 14.2 per cent., while in 1872 and 1873 it was about 16½ per cent. The reason this proportion is so large is explained by the fact that Mr. Bannan included in "home consumption" the coal delivered by the transportation companies at certain points along their lines not remote from the coal-fields.

In my returns of 1874, 1875, and 1876, which have been compiled with the greatest care (the figures for 1876 are *approximate* only, it being yet too early to make the final corrections, but the totals given will not be materially modified by these), I limit the "consumption at the mines" to coal not transported by the railroads or canals, and consequently consumed by the miners, the engines, the locomotives in the coal-fields, and such towns as are partially or wholly supplied by wagons direct from the collieries. I have full and accurate reports of several of these items, and my information leads me to the conclusion that five per cent of the shipments as now given by me will represent the "consumption at the mines." This statement will explain the fact that while Mr. Bannan's tables give since 1864 the correct total production, as nearly as can now be ascertained, his division into shipments and home consumption being made upon a different basis from mine since 1873, cannot be compared with these.

The above, then, is the first and only statement that has ever been made of the total anthracite production of Pennsylvania. From an inspection of it we note the marvellously rapid development of this trade, and we also observe the severity of the check which it has received during the last three years under the combined influence of the financial crisis and the combination high prices. It is the first instance in the history of the trade where the production of anthracite has decreased during three successive years, and, what is still more discouraging, the actual amount of this decrease has been growing greater year by year. Had it not been for the great decline in prices which followed the dissolution of the combination, there can be no doubt the production during 1876 would not have exceeded 17,500,000 or 18,000,000 tons. As it is, the actual decrease is the greatest the trade has ever suffered in one year.

The amount of the production in 1876, which is given as 19,000,000 tons, is, it is true, merely approximate, but it will not be varied materially by final revision—probably less than one per cent.; so that for purposes of general comparison it may be safely adopted.

ON THE DETERMINATION OF CARBON BY MAGNETIC TESTS.

Being the Results of Tests made at the Works of the Otis Iron and Steel Company, Cleveland, Ohio, under the direction of the Manager, Mr. S. T. Wellman.

BY CHARLES M. RYDER, CLEVELAND, OHIO.

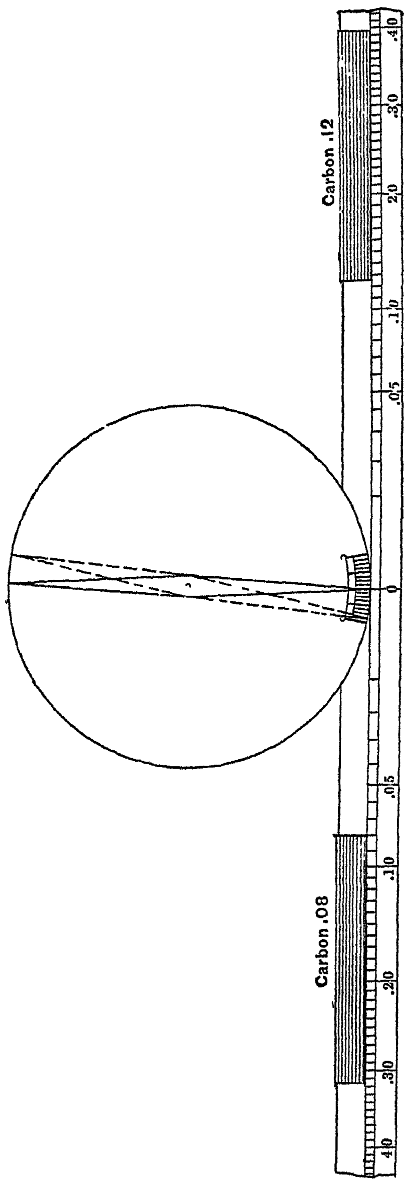
IN presenting this paper to the Institute I beg to mention, first, the results which I have obtained and the apparatus which I have employed, and to follow this with a brief description of the steps by which I have perfected this process.

My present mode of testing is as follows: I obtain, either from the furnace or from the finished product in any stage in which it may chance to be, a small test-piece, usually about $\frac{3}{4}$ of an inch square by $3\frac{1}{2}$ inches in length. I place this test-piece upon the poles of an ordinary electro-magnet, for about one minute, and thus magnetize it to its extreme limit. I then place it upon an indicator (which I will shortly describe), on which indicator there is already placed a piece of steel of similar form which has been magnetized in the same manner, the percentage of carbon of this second piece being definitely known. I then, by means of a scale, which forms part of the indicator, marked in degrees of carbonization, read the exact percentage of carbon contained in the piece under examination.

My apparatus consists of an ordinary electro-magnet, connected with a suitable battery of moderate power, by which I magnetize the pieces as before described, and of an indicator which consists of a magnetic needle suitably mounted or suspended, so that it is free to deviate a few degrees only from the zero point, and having a rest, which is used to check the vibrations when in use, and to support its weight when not in use. At a right angle to the natural position of the needle I have a scale about 3 feet long, the zero point of which coincides with the natural position of the needle. This scale is marked in each direction from the zero point in degrees of carbonization.

The marking of the scale is in accordance with the following rule: Taking the carbonization of the steel as a basis, I maintain the same proportion between the squares of the distances on the scale as exists between the percentages of carbon in the steel, for instance, if .08 of

one per cent of carbon is marked at 4 inches from the zero point, then, .32 of one per cent. would be marked at 8 inches from the zero



PLAN OF
MAGNETIC CARBON INDICATOR
used by
CHA'S M. RYDER.

point, since the square of $4 = 16$ bears the same proportion to the square of $8 = 64$ that 8 does to 32.

On this scale I place the test-pieces of steel, the one of known carbon being placed in one direction from the zero point, so that its end nearest the needle shall be at the figure on the scale which represents the percentage of carbon which it contains, and the unknown piece being placed on the opposite end of the scale, is moved along the scale until the needle maintains its natural position at the zero point. The end of the unknown piece nearest the needle will then rest at a figure on the scale which represents the percentage of carbon which it contains. The indicator is also provided with levelling and adjusting screws for keeping the needle in its natural position.

Such, in brief, is the present method I use, being the result of some three months' experiment with test-pieces of known carbonization. So far as accuracy is concerned, I have compared these tests with repeated chemical tests of our most trustworthy chemists, and with the mechanical working of the steel, and I am convinced that, owing to the simplicity of the process, the readiness with which it may be repeated or proved with a number of standards of different carbonizations, and the fact of its dealing with a larger mass of metal than is used for chemical tests, it gives a more correct indication of the percentage of carbon in a mass of steel than the ordinary tests of the best chemists; while for carbons ranging from .04 of 1 per cent. up to 1 per cent. I can determine the carbon more accurately in one reading than it can be determined by the color test in five or six, provided, in both methods, that the carbon is not even approximately known.

As regards the time required for an accurate test, I have cast tests from metal in the open-hearth furnace, cooled them in a blast of cold air, and read the carbon in something less than five minutes, my apparatus being some 300 feet removed from the furnace. In testing the finished product, which may be of any uniform shape and size, one test-piece may be kept on the magnet and one at the indicator, so that the reading is very rapid.

I will now give a brief sketch of my experiments and observations. I began operations with a small pocket-compass, using the ordinary open-hearth test ingots, slightly magnetized by breaking, having accidentally observed that they exerted different powers on the magnetic needle. Convinced that nothing could come from these experiments with irregular shapes, I next tried pieces which had been pulled asunder in a testing machine, with which I obtained quite good results. I then constructed a small needle which I suspended in a glass jar, placing the jar on a sliding-scale arrangement, similar

to my present form, except that the scale of carbonizations was a scale of equal parts. By accident the angle which the low carbons presented to the needle was such, that with pieces of a certain form the readings were very correct, and for some time I supposed the scale of equal parts to be correct. A change in the form of the test-pieces, however, soon showed the error.

About this time I began using the electro-magnet for magnetizing the pieces, and was led into some errors by placing the sides of the test-pieces in close contact with each other. This increases the comparative difference of two pieces of different carbonization, so that the reading on the indicator is not correct.

For absolute accuracy I prefer that both the standard and the piece to be tested shall be placed side by side upon the electro-magnet, in the neutral condition, *i. e.*, being entirely without magnetic force, which condition is obtained by simply heating the pieces red-hot, and allowing them to cool slowly, and I am having a magnet constructed with which I hope to magnetize a large number of pieces at the same time, side by side, thus multiplying the proofs of the first reading.

So far as this neutral condition is concerned, I have used the same test-piece for a standard for some weeks without paying any regard to it, merely placing the standard on the magnet each day and restoring what force it had lost by time. I have also found it impossible to exceed a certain amount of force, even by keeping it on the magnet for half a day, the extreme limit being reached in one minute. The test-pieces may be used hardened or tempered, but I have obtained the best results without hardening the pieces.

Since perfecting my experiments and applying for letters-patent for the United States, I have had brought to my notice a work published in London in 1839, entitled *Scoresby's Magnetical Investigations*, written by the Rev. Wm. Scoresby, in which I find many similar experiments, the object of which was to perfect the manufacture of magnetical instruments, such as sea-compasses, etc. But owing to the crude state of steel-making at that time, as compared with its present condition, and the still more noticeable lack of knowledge as regards the chemical elements of steel, "the writer of the work not being connected with the steel industry," he seems not to have arrived at any practical or useful test to determine the elements of steel, but only to tell whether it was suitable for magnetical apparatus.

I will quote a few passages from this work. In Chapter VII, p. 74, Scoresby says:

"The principles of inductive science lead directly to the conclusion that the sustaining power of the magnetic condition in a mass of steel should afford the means of determining, as to the degree of carbonization at least, the quality of such steel, for as simple uncarbonized iron, notwithstanding its high capacity for magnetism, possesses extremely little power of retention, and as thoroughly carbonized iron, with no higher, but rather a lower capacity, has very great capability for permanent magnetism, the inference becomes obvious, and the conclusion apparently inevitable, that a partial degree of carbonization must be attended with a limited measure of sustaining energy."

On page 80, he adds:

"And perhaps it is not unreasonable to expect that, were all the varieties of magnetic capacity in each denomination of steel, and in each quality, as respects the kind of iron out of which the steel is converted, experimentally ascertained, a strictly scientific process of testing, founded on these principles, might be devised—a process which might possibly exhibit results, if not as exact, at least as conclusive in certain most important relations of value in the metal, as are obtained by the beautiful process of assaying."

Again, on page 81:

"Subsequent experiments, which to a considerable extent I have made, have served still further to support the general views above stated; but they have not been pursued sufficiently far for the determination of the precise effects of the various differences in the methods of the manufacture of steel, or modes of tempering it, by which its magnetic properties may be modified."

Dr. Scoresby's work has much more of value to a maker of magnetic instruments, but I do not find anything of value to a steel manufacturer, as the analysis of the samples which he used are in no case given.

I accompany this paper with a sketch of my apparatus.

SUPPLEMENTARY COMMUNICATION ON THE DETERMINATION OF CARBON BY MAGNETIC TESTS.*

Being a record of some additional investigations made at the works of the Otis Iron and Steel Company, Cleveland, Ohio.

During the four months that have passed since my first communication to the Institute, I have had my method of determining carbon in constant use, testing every variety of steel produced at the works, both by taking tests from the furnace and by tests taken from the product in the various stages of manufacture. It has been my endeavor to ascertain by the tests taken at the furnace and from the ingots just what the mechanical working of the finished product would be, in advance of the actual use of the steel, and I have succeeded in this undertaking even better than I expected to. I have been able to determine the tensile strength of bars and plates very closely, the indications of carbon by my apparatus in most instances agreeing better with the breaking of the specimens in the testing machine than any previous chemical tests.

The medium grades of steel I have tested by bending under a steam-hammer, and have found an equal degree of uniformity to exist between the carbon indications and the mechanical test. Spring steel I have tested by making springs from a single bar, and testing under steady pressure and sharp blows with a steam-hammer. None of the samples showing a proper degree of carbonization have failed to stand both blows and pressure. I have found this method of great value in testing the steel during the process of manufacture in the mill, any shearing or end of bars or plates being used as test-pieces whenever I desired to ascertain its fitness for a certain use. The quickness and simplicity of this method for testing steel in bars or plates will make it of great value to parties handling or using considerable quantities who have no facilities for other tests.

An apparatus can be designed for this particular use, at a slight expense, which may be portable and would be ready for use at any moment, the whole being contained in a case less than two feet long and six inches deep.

My investigations have also proved to my satisfaction that the percentage of manganese in steel may be estimated by this apparatus, not as closely as carbon, but close enough to be of great value to a steel-maker, and that the simplicity of the test is not materially

* Read at the New York meeting, February, 1877.

affected by this new element. I have not perfected this feature as much as I hope to, but think I can determine the manganese in any sample of sufficient size, at least within .10 of one per cent. of the actual analysis. Slight differences, or such as are expected to occur in the manufacture of steel for a particular use, will not affect the carbon indication; but wide differences in this element have an important influence on the indication, and if a standard is used in testing which is just right for the particular purpose for which the steel is intended, any improper proportion of manganese would not pass unnoticed.

The electro-magnet to which I alluded in my first paper has proved a success, and it was by means of this that I first obtained satisfactory tests of manganese.

I have watched closely for the effects of various impurities on this process, but have not noticed any particular effect from the presence of phosphorus or other impurities in the steel.

THE VOLUMETRIC DETERMINATION OF SULPHUR AND AMMONIA IN ILLUMINATING GAS.

BY H. E. SADLER AND PROF. B. SILLIMAN, NEW HAVEN, CONN.

INTRODUCTORY NOTE.

THE research here recorded was undertaken early in the present year, and has been prosecuted steadily for about eight months. While the work has been under my constant supervision and advice, the labor has all been performed by Mr. Sadler, to whom is chiefly due the development of the successive steps which have led to the final result. The process is better than I dared to hope, and we are able to place at the command of chemists and engineers interested in the matter an apparatus of continuous and uninterrupted action, and methods of analysis by which the daily averages of the two variable and inconstant factors of illuminating gas, ammonia and sulphur, may be determined with all needful accuracy, even by those little skilled in chemical manipulation, and with very little loss of time.

This research has been carried out in the laboratory of the New Haven Gaslight Company.

B. SILLIMAN.

October 17th, 1876.

Introduction.—In making some determinations of the sulphur in coal gas by the Letheby apparatus, the importance of some simpler process was forcibly suggested by the experience, skill, expense, and time required to obtain trustworthy results. The chances of error were numerous. Insufficient washing of the apparatus, with the liability of breakage in daily handling, the care required in the concentration and in the expulsion of the ammonia, the varying solubility of barium sulphate in presence of indefinite quantities of ammonium nitrate and free acid, the tendency of that precipitate to run through the filter, the opportunities for loss in the incineration and ignition, the expense of the analytical balance, with the delicacy of manipulation which it requires, and, above all, the time involved,—from four to eight hours after the gas is burned,—all these seemed to place the Letheby test beyond the possible for the practical gas manager.

To escape, without the sacrifice of accuracy, these numerous drawbacks was the end proposed. The result attained is a simple process for the volumetric estimation of the sulphur, dispensing with the balance, and requiring but ten minutes for a determination. The apparatus at the same time affords the working engineer a continued and ready check upon all his purifying processes except the removal of the tar.

Description of the Apparatus.—The apparatus represented in Fig. 1 is of glass, except the governor, *b*, the meter, *i*, with its connections, and the burner with its case, *k*, which are of metal. *d* performs the office of a scrubber. It is an inverted calcium chloride or bubbling tube, of about 600 c. cms. capacity, with a third hole drilled for the admission of the stopper, *h*, which carries a wire to support ammonia, acid, and hydrogen sulphide test-papers. The larger cylinder is filled with broken glass and supplied with standardized acid from the bottle, *u*, by means of the siphon-tube, *g*, which is fitted with a stopcock. The gas is admitted by the tube, *c*, extending 5 cms. into the cylinder, and the acid escapes into a flask below by the tube, *e*, which is bent to form a seal. The meter and burner are substantially those used by the referees.* The adapter or eductor, *l*, is 50 to 60 cms. high, the diameter at the base about 7 cms., and the smallest internal diameter at least 1½ cms. *m* has a diameter of 2 cms., with an opening drawn out at the bottom

* First report of the Gas Referees upon the sulphur question, July 13th, 1870. Reported in London Journal of Gaslighting, etc., August 16th, 1870.

for the escape of the drip from *n*. *n* is a strong tube $3\frac{1}{2}$ cms. in diameter by 80 cms. long, filled with glass marbles $1\frac{1}{2}$ cms. in diameter. This tube serves as a condenser and also to break up the ascending current from the burner and bring it into intimate contact with a standard alkali, dripping upon the marbles through the tube and stopcock, *o*, from the pipette, *p*. This measures 200 c. cms. by halves, and is 60 cms. long. At the beginning of an experiment it is filled by the three-way pipe, *q*, from the bottle, *t*, by opening the pinchcock, *r*.

The apparatus is most conveniently mounted against the wall, the meter and bottles standing upon shelves, and the burner and flasks upon swinging brackets. The remaining parts are then secured by clamps driven or screwed into the wall.

Mode of Manipulation.—Solutions of caustic soda or potash and an acid, sulphuric or oxalic, are provided of such strength that 1 c.c. has a saturating power exactly equal to $\frac{1}{10}$ grain of sulphur in the form of sulphurous or sulphuric acid.* The containing bottles and the pipette

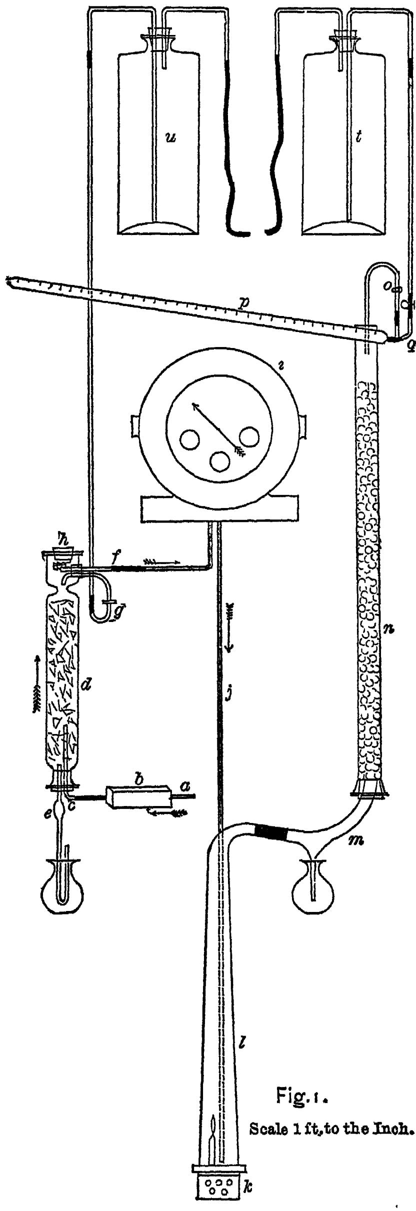


Fig. 1.
Scale 1 ft. to the Inch.

* The standard solutions can be purchased of chemical dealers, and no balance will then be needed. They may conveniently be made of ten times the strength indicated, and portions withdrawn and diluted to this strength as required.

being filled, the gas is lighted and regulated by the governor, as near as may be to the rate of ten feet in twenty-four hours. The stopcocks in *o* and *g* are then opened so that 10 c. cms. will pass each for one foot of gas burned.* After half an hour or an hour, when the apparatus has attained its normal working, a clean flask is placed under each drip, while the meter and the quantity of alkali solution in the pipette are accurately noted.

When, thereafter, 10 feet have passed the meter, which will be in about twenty-four hours, the quantity of alkali which has flowed from the pipette is determined and the flasks are removed, others being substituted if a test is desired for the following day.

The free and carbonated alkali present in the drip is then to be saturated with the standard acid, but since with litmus and even with cochineal† the carbon dioxide obscures the point of neutralization, it is best to add a quantity of acid equal to the total alkali used, and, after removing the carbon dioxide by boiling the liquid for a brief interval, to titrate back with the standard alkali. The number of c. cms so used expresses the number of grains of sulphur in 100 feet of gas. For the alkali received in the drip being just saturated by the standard acid, the free acid there will be the quantity caught from the gas. Now, since 1 c. cm. of the alkali finally added is saturated by one-tenth grain of sulphur, one-tenth of the c. cms. added indicates the number of grains caught from the 10 feet burned, and ten times this the quantity of sulphur in 100 feet.

The acid solution used in the scrubber is also measured and the acid remaining free determined by the standard alkali. The difference expresses, as in the case of the sulphur test, the number of

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* Great difficulty was experienced in securing an uninterrupted and uniform flow of the solutions. The purest distilled water seemed to carry down impurities sufficient to choke the capillary opening of the stopcocks, which at the proper rate pass but four drops per minute. Filters of Swedish paper, of cotton batting, of fine linen cloth, and of sand were tried in vain. The simple device of passing the solution through the stopcocks in ascending, instead of descending currents, which placed the force of gravity in opposition to, instead of in accord with the slow suction of the streams, afforded instant and complete relief.

† Hæmatoxylin was first chosen as an indicator, both because it is the most sensitive to minute quantities of free acid and alkali, and because the change of color, yellow to port wine, is the most conspicuous. But in this solution the reaction was very unsatisfactory. The color changed gradually from yellow to reddish-brown. The absence of metallic salts, at least of the heavy metals, was well demonstrated, and there seemed no explanation of the phenomenon except that the coloring-matter was oxidized by the nitrous acid present, and rapidly destroyed. Cochineal was therefore substituted, and proved very satisfactory.

grains of sulphur which can be neutralized by the ammonia in 100 feet of gas. Since 1 grain of sulphur neutralizes $1\frac{1}{16}$ grains of ammonia, if the number of c. cms. of acid neutralized by the ammonia be increased by $\frac{1}{16}$th, the sum will express the grains of ammonia in 100 feet. This may be accomplished mechanically by having the ammonia measuring-glasses graduated so that 17 divisions shall be equal to 16 c. cms.

The conditions indicated are the most convenient for continuous daily determinations. They are not essential to successful working. On the contrary, two feet of gas are sufficient to give reasonably accurate results, and the apparatus has not proved unequal to a rate of one foot per hour. Moreover, much less acid, run through the scrubber, would be usually sufficient. The quantity of ammonia to be arrested during the period of these experiments was abnormally large, pending a rearrangement of the scrubbers at the works.

Efficiency of the Apparatus.—The following results were obtained from an apparatus which differed from that figured only in that the eductor, *l*, and the condensing-tube, *n*, were each one-third shorter than described. It was worked first in comparison with the Letheby test, taking the gas from the same supply-pipe, and burning it during the same interval, at nearly the same rate, about two-thirds of a foot per hour. From two to four feet, according to convenience, were taken for each experiment.* The Letheby was supplied with about 100 c. cms. concentrated liquor ammonia. However, this rule was not invariable, and, with three or four of the experiments which cannot now be specified, a weaker solution was used. No result, however, is reported, or was worked out, in which at the end of the burning an exposure of three seconds at the escape failed to turn turmeric paper deep brown. The condensation and washings were evaporated on the water-bath to about one-half, treated with bromine, heated to expel any great excess, precipitated while boiling with barium chloride, allowed to settle, the supernatant liquid, and finally the

* It may be remarked that in the Letheby test, as described in Sugg's "Gas Manipulations," the gas is burned in an atmosphere strongly ammoniacal. The products of combustion are carried into a large glass cylinder, where the resulting ammonium sulphite and sulphate fall with the condensing vapor of water, passing into solution. The sulphur is then converted into the form of barium sulphate, and weighed. In the apparatus used, a second condensing cylinder was added, and a trial with a further addition of ten feet of tubing, as a condenser, showed that less than one-half of 1 per cent. of the liquid escaped.

powder, decanted on to a filter, washed with hot water so long as the washings showed the presence of barium, dried, ignited, and weighed, the filtrate being always tested for sulphuric acid.

The other apparatus was supplied with from nine to twelve c. cms. of the standard soda solution for each foot burned. The gas was taken directly from the governor to the meter, without the interposition of the ammonia test, and the drip having been slightly acidified with hydrochloric acid, and further with bromine water, was boiled, and the contained sulphates precipitated hot with barium chloride, and treated thereafter as in the Letheby determinations.

The following table gives the results:

TABLE A.

Date.	Sulphur caught. Grains per 100 feet.	Sulphur caught by Letheby Grains per 100 feet.	Excess over Letheby. Grains per 100 feet.
May 15th, . .	18 64	12 44	6 20
" 16th, . .	19.62	13.70	5.92
" 17th, . .	18 54	14 01	4.53
" 22d, . .	19.33	12 38	6 95
" 23d, . .	18 15	12 11	6 04
" 24th, . .	17.64	11 64	6.00
" 25th, . .	16 58	13.04	3.54
" 26th, . .	14.25	10.21	4 04
" 27th, . .	18.43	10 47	8.43
Total, . .	161.65	110 00	51 65

Average gain over Letheby, ... 46.95 per cent.

The only means at hand for comparing the new apparatus with the referees' is through the Letheby. In their description of their test, before referred to, a table is given in which the following determinations only are strictly comparative:

TABLE B.

Referees.	Letheby.	Excess.	Referees.	Letheby.	Excess.
Grs. Sulphur per 100 feet.	Grs Sulphur per 100 feet.	Grs. Sulphur per 100 feet.	Grs Sulphur per 100 feet.	Grs Sulphur per 100 feet.	Grs. Sulphur per 100 feet.
33 4	25 1	8 3	35 0	21 86	13 14
35 5	24 4	11.10	34 73	24 92	9 81
32 6	22 2	10 4	34 98	25 82	9 16
31 8	23 8	8 00	34 8	25 24	8 56
29 2	23 9	5 3	35.5	25 4	10 1
29.6	24 9	4 7	36 26	25 12	11.14
31.17	24 9	6 27	27.4	18 4	9 0
31 4	25 4	6 0	28.0	19 2	8 8
32.27	25 8	6 47	27.7	23 3	4.4
32 8	25 24	7.56	26 6	20 6	6 0
31 6	24 32	6 28	28.03	20 4	7 63
32.96	23 96	9 0			
34 41	23 35	11.06	379.85	577 53	197.68

Average gain over Letheby, ... 34.2 per cent.

And in the place cited, Dr. Odling reports the following comparative workings:

TABLE C.

Referees.	Letheby.	Excess
Grains Sulphur per 100 feet.	Grains Sulphur per 100 feet.	Grains Sulphur per 100 feet
26 41	21 04	5 37
25.60	19 32	6 28
21.33	19 76	1.57
21.04	17 48	3.56
94.38	77.60	16.78

Average gain over Letheby, ... 21.06 per cent.

A comparison of these workings seems to indicate that in efficiency this apparatus does not differ materially from that of the referees; for while the percentage of gain over Letheby's is considerably larger, it will be noticed that the quantity of sulphur to be caught was less, and the actual number of grains caught in excess of the Letheby is in favor of the referees' test. Perhaps no apparatus arrests absolutely all of the sulphur, and the real usefulness of sulphur tests consists in indicating the relative amounts of sulphur in

the gas from day to day. A consideration of these tables forces upon one a conviction of the entire worthlessness of the Letheby test for even this purpose, a defect which the experience and carefulness of Dr. Odling himself has not overcome.

A third sulphur test is that of Mr. F. J. Evans, who drew the products of combustion through an alkaline solution contained in Woulfe bottles. It is to be regretted, in this connection, that no figures could be obtained showing the result of his workings and affording a comparison of the new test with his, and that no opportunity has been offered to compare its simplicity or accuracy with the test devised by Mr. Vernon Harcourt, and described at the last meeting of the British Association of Gas Managers.

Volumetric Estimation of the Sulphur.—Having so far demonstrated the efficacy of the new apparatus, the Letheby test was discarded, and the determinations of the sulphur hereafter given were made by precipitating the sulphur in the drip from the new apparatus by barium chloride, in the manner already described. The apparatus was not changed, except to introduce the tube *d*, to arrest the ammonia which, previously passing through the flame in undetermined quantities, had vitiated the volumetric estimation of the sulphur acids by standing alkali solution. The alkali used was caustic soda. For the scrubber, standard sulphuric acid was chosen on account of its slight volatility, and in order that the absorption of acid vapors by the gas, then deemed possible, might not complicate the results by introducing a new acid into the products. To saturate the alkali in the drip, standard hydrochloric acid was chosen, as it permitted a gravimetric estimation of the sulphur in the portion taken after it was titrated, avoiding alternate sources of error, either the estimation of the total sulphur introduced with the sulphuric acid, or obtaining two separate portions of the drip, having in solution exactly equal quantities of acid and of sulphur. Moreover, though free hydrochloric acid is somewhat volatile in boiling solution, experiment demonstrated that, with the degree of dilution and heat employed in these determinations, the loss was unappreciable. A 100 c. cm. pipette, and a burette measuring 100 c. cms. by tenths, were used for supersaturating the alkali with acid, and a 25 c. cm. burette graduated to tenths, for titrating back with the soda. For each determination a portion of the drip resulting from the combustion of from 6 to 10 feet of gas was taken, divided into two measurably equal portions, and duplicate experiments carried

through, as shown in the following table, the results being calculated to grains in the hundred feet.

Table D.

No. I	Date II.	Acid caught per 100 ft, expressed in grs, Sulp'r. III.		Grains of Sulphur caught, per 100 feet. IV.		Excess. Acid V	Excess. Sulphur. VI.	Excess of acid corrected VII	Soda c cms per foot of gas burned VIII	Rate, feet burned in 100 min. IX
	Aug									
1	22–3	38 55 / 38 65	38 60	39 34	39.34	.... .	0.74	—0 74	7 90	1 064
2	23	46 91 / 46 58	46.74	41 33 / 41 42	41 37	5 37*	.... .	(—0 10)	9 75	1 026
3	23–4	35 99 / 35 93	35 96	35 28 / 34 76	35.02	0 94	......	+0 94	12 28	1 023
4	24	30 55 / 31 25	30 90	33 95 / 32 46	33 20	.. .	2 30	—1 21	13 67	1 056
5	24–5	35 28 / 36 01	35 64	34 48 / 32 60	33 54	2.10	.... .	+0.60	10 65	1 041
6	25	36 61 / 35 95	36 28	34 55 / 34 23	34 39	1 89	.. .	+1 89	12 80	1 026
7	28	34 20 / 34 29	34 20	35 50 / 35 37	35 43	. .. .	1.23	—1.23	9 44	1 035
8	29	38 98 / 38 98	38 98	39 53 / 39 62	39 58	... ..	0.60	—0 60	11 70	.996
9	30	36 01 / 35 68	35 84	35 80 / 35 22	35 51	0 33	......	+0 33	13 33	.984
10	30–1	33 27 / 32 91	33 09	32 25 / 31 96	32 11	0 98	. .	+0 98	9 90	10.22
	Sept.									
11	31–1	33 63 / 33 79	33 71	34 38 / 33 86	34 12	. .	0.41	—0 41	10 87	.987
12	1–2	35 84 / 35 54	35 69	33.91 / 33 74	38 82	1 87	... . .	+1 87	9 95	.988
13	2–3	34 87 / 35 00	34 93	33 06 / 33 06	33.06	1 87	....	+1 87	10 99	966
14	3–4	31 92 / 32 58	32.25	31 40 / 31 44	31 42	0.83	.... .	+0 83	10 79	944
15	4–5	31 90 / 32 07	31.98	30 09 / 30 30	30 20	1.78	....	+1.78	10 20	.957
16	5–6	26 03 / 26 51	26 27	26 46 / 26 91	26 28	..	0 41	—0 41	9 65	940
17	6–7	24 81 / 24 81	24 81	24 36 / 24 33	24 35	0.46	. ...	+0.46	10 47	.943
18	7–8	22 36 / 22 36	22 36	20 12 / 20 27	20 20	2 16	.. ..	+2.16	13.19	.897
19	8–9	18 43 / 18 44	18 43	18 92 / 18 93	18 92	.... ..	0 49	—0 49	10 75	960
Average errors.						1 29	0.75	.. .	..... .	. ...
Average total errors.						0 27	.. ...	....	.. ..	. ...

It will be seen by comparing columns III and IV that the acid caught indicates the quantity of sulphur in the gas with tolerable

* An error of 2 c.cms., in determining the quantity of alkali used would have made this result —0.10. An exactly similar error in experiment No 15 was discovered in time to be corrected. At all events, this result is so abnormal that it seems proper to disregard it. It will be noticed that, throughout, the duplicate experiments accord fairly with each other. In two instances, however, they differ by more than 1 grain per 100 feet, viz , in experiments Nos 4 and 5. It is probable, since they cannot both be nearly right, that one is entirely wrong, and therefore, in computing column VII, only that result is taken which is most in accord with the other experiments.

accuracy, sufficient for all manufacturing purposes. Columns V and VI give the excess of acid and sulphur in terms of grains of sulphur to the hundred feet. The average error in favor of the acid is 1.29 grain, and in favor of the sulphur 0.75 grain, making the average total error 0.27 grains in favor of the acid. Assuming this as a constant quantity which, being deducted from the acidity found, gives the sulphur, we have as a limit of error in favor of the sulphur (No. 4) 2.03 grains, in favor of the acid (No. 18) 1.89 grain. We may say, then, that one grain to the hundred feet is the average error, and two grains the limit of error for the volumetric determination of the sulphur in gas by this apparatus.

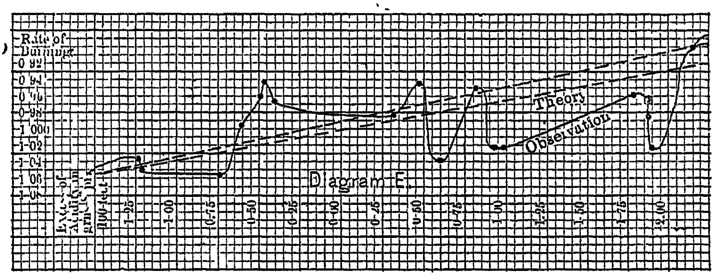
The Formation of Nitrous Acid and other Sources of Error.—In endeavoring further to reduce or eliminate this variation, the drip from the condensation-tube was carefully tested for other acids and bases. Besides the soda and sulphuric acid, nitrous acid, probably mixed with nitric, was detected by silver nitrate, and also on setting free the nitrogen acids with sulphuric by the coloration tests, ferrous sulphate, brucia, etc. No other acids could be found—carbonic, of course, excepted. The absence of sulphurous acid or a soluble sulphite was a surprise. It was demonstrated by precipitating duplicate samples, oxidizing but one of them. The resulting precipitates did not differ sensibly in weight. This fact was further confirmed by adding 10 c. cms. of a carefully titrated solution of potassium sulphite to successive equal portions of the drip. On titrating back with standard iodine solution and starch paste, it was found that 5.65 c. cms. of the sulphite in each solution had been oxidized. Of the bases a trace of ammonia alone was found. The drip in experiment No. 12 was submitted to Nessler's test, and showed $\frac{9}{10}$ grain of ammonia per 100 feet, equal to $\frac{84}{100}$ grain of sulphur. The nitrogen acids were not determined, as no means for the estimation of so small quantities presented itself, except the somewhat difficult combustion process. It seemed impossible* that more than $\frac{1}{100}$ grain of ammonia could be supplied by the 700 feet of air admitted by the apparatus for the combustion of 100 feet of gas, and it followed that the remainder must be produced in the burning. There was no other source for the nitrogen acid.

We are brought here face to face with a curious phenomenon.

* See Johnson's "How Crops Feed," p. 55, and especially Viele's determinations, Pelouze and Fremy, I, 320.

Nitrogen, forming simultaneously under the same conditions, an acid and a basic radical with the oxygen and hydrogen directly or indirectly supplied by the air and gas respectively.

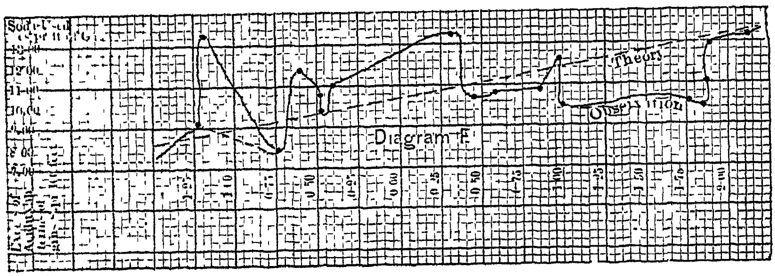
This fact has been before noted and more clearly proved.* Two theories present themselves in this connection to account for the variations noted in the above table between the sulphur and the total free acids produced by the combustion. The first is that where the gas is passing rapidly and the flame is near the smoking-point, the nitrogen will find an abundance of hydrogen from the gas and a scanty supply of oxygen. The tendency will then be to form ammonia in excess of nitrous acid. When, on the contrary, the gas is burned slowly and the supply of air being the same, a surfeit of oxygen awaits the scanty hydrogen, acid will be more freely formed than ammonia. The excess of total acidity will then be a function of the relative supply of gas and air, and column VII will follow column IX, which gives the rate. How far our experiments sustain this view will be seen from diagram E.



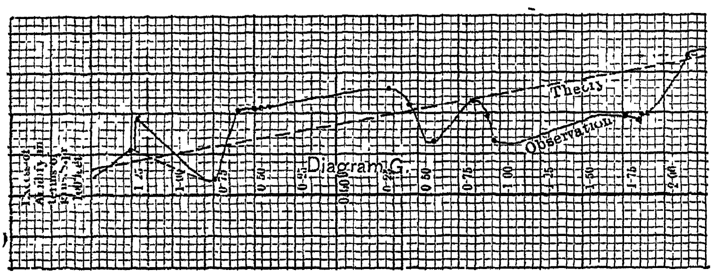
The second theory plants itself upon the hypothesis of the dual nature of nitrogen gas, one atom of each molecule broken up in nitrification taking to itself hydrogen and the other oxygen. In this case an excess of acid or base from the nitrogen is impossible, the product of nitrification being uniformly ammonium nitrate, a salt. This substance, however, is very unstable, falling readily back to water and nitrogen, and yielding easily to an acid, ammonia, to a base, nitrous acid. Thus, this body, in passing through the condensing-tube, would surrender its acid to the soda in amount somewhat proportionate to the quantity of free soda in the tube, while

* Schaeffer, Am. Jour. Sci., Nov. 1868 T. Sterry Hunt, Chemical and Geological Essays. Appendix, p. 470. Shönbein, London and Edinburgh Philos. Mag., June, 1862, p. 466.

the ammonia, but slightly absorbed by the alkaline solution, would pass off at the escape. Column VII would then accord in some sort with column VIII, which gives the relative proportion of soda and gas used in each experiment. Diagram F shows the variations.



To pronounce upon the accuracy or sufficiency of either proposition without further experiments made with especial reference to them would be premature. Probably outside of certain limits which we may call the normal working, both the rate and the alkali used have their influence on the result, as will appear more clearly by comparing the two curves given above with the curve of their average as shown in diagram G.



For the rest, the perturbations must be charged to the inaccuracy of the test as worked, of which there are several sources which, small in themselves, may yet be considerable in the aggregate. First, we assume that, at the end of an experiment, the condensing-tube contains the same quantities of alkali and of sulphur as at the beginning. The difference, when compared with the total quantity, must be small, but a difference there may be. Second, the alkali pipette attached to the apparatus, the acid pipette and burette, and the alkali burette must be strictly accurate; at least they should accord with themselves and each other. The former of these conditions was not

in our apparatus entirely fulfilled. Third, the opportunity for error is considerable in judging the change of color with cochineal, especially when the determinations are made on different days and cannot be compared with each other; and lastly, the "personal error" cannot be entirely disregarded.

Other Products of the Combustion.—Aside from the acids and bases, no substance among the products of combustion was positively identified. Potassium iodide paper, moistened with starch liquor and suspended above the marbles in the condensing-tube, immediately showed the presence of an oxidant, probably hydrogen dioxide or ozone, since nitrous acid was hardly possible after passing this alkaline solution. Blue litmus-paper, however, was here reddened, but rapidly bleached. The reddening was probably due to the carbon dioxide.

A portion of the drip from each of the last eight experiments was preserved in tightly stoppered bottles, and at the conclusion of the experiments tested for oxidants, with one-twentieth normal sodic hyposulphite and iodine solutions. No oxidation of hyposulphite took place in alkaline solution. Upon acidifying with hydrochloric acid, from one to two c.cms. were found to be oxidized. After adding excess of hyposulphite, and allowing the solutions to stand,—Nos. 12, 13, and 14 over night, and the rest for one hour,—the following results were obtained. Since no oxidation took place in the alkaline solution, it was inferred that nitrous acid was the oxidant, and not hydrogen dioxide nor ozone, and the results are accordingly expressed in grains of nitrogen oxidized in the combustion of 100 feet of gas:

TABLE H.

	Grains N.		
No 12.	0 988	equal in saturating power to . . .	0 86 grains of sulphur.
" 13.	0.739	" " " . . .	0 65 " "
" 14.	0 706	" " " . . .	0.62 " "
" 15.	0 415	" " " . . .	0.36 " "
" 16.	0 411	" " " . . .	0.36 " "
" 17.	0 354	" " " . . .	0.31 " "
" 18.	0.291	" " " . . .	0 26 " "
" 19.	0.244	" " " . . .	0.21 " "

These results seem to indicate so unquestionably that much the greater part of the oxidation was due to the atmospheric air absorbed by the liquid, that it is barely worth while to recall in this connection the Nessler determination of the ammonia in No. 12, $\frac{9}{10}$ grain per 100 feet, equal in saturating power to 0.84 grain of sul-

phur. The above table shows nitrous acid in No. 12 equal to 0.86 grain of sulphur.

Further Suggestions.—The possibility of avoiding the complication arising from the arrest of varying quantities of nitrogen acids, and of further simplifying the working of the test by substituting pure water for standard alkali in the condensing-tube, is suggested by a consideration of the fact that sulphuric oxide possesses so great affinity for water, and that, when once in solution, especially if the proportion of water is large, only slight traces of acid vapors are given off, even under the most favoring circumstances.

It may be true that, in the combustion of sulphur, sulphurous and not sulphuric oxide is the body immediately produced; but it is rendered probable by several experiments, most of which have been detailed above, that travelling in company with the powerful oxidants produced by the combustion of hydrocarbons in air, no considerable quantity of sulphur would enter the combustion-tube without being completely oxidized—a view which receives confirmation from the important experiments of M. Vérigo, communicated to the *Académie des Sciences* by Berthelôt, and reported in *Comptes Rendûs* for April 24th, 1876.* If this inference prove unfounded, we have still a safeguard in the comparatively ready solubility of sulphurous oxide in water with which the products of combustion are very thoroughly scrubbed in the condensing-tube; and, as a last resource, the addition to the scrubbing water of a small quantity of standard solution of borax, which is a great solvent for sulphurous oxide.

While still under the impression that sulphurous acid was the chief substance to be met with, some experiments which depended for success upon the power of water to arrest sulphuric oxide, as suggested above, gave the following results:

TABLE I.

No. 1.	14.93	grains	S. per	100 feet.
" 2.	31.53	"	"	100 "
" 3.	17.51	"	"	100 "
" 4.	10 51	"	"	100 "
" 5.	10 48	"	"	100 "
" 6.	18.60	"	"	100 "
" 7.	18.43	"	"	100 "
" 7 Letheby.	15.34	"	"	100 "

* Since this paper was read, our attention has been called to the fact that Charles Heisch, F.C.S., had already observed the absence of sulphurous acid (London Journal of Gaslighting, etc., December 29th, 1874, p. 856), and in the October number of the American Chemist are reported some experiments of W. C. Young, F.C.S., leading to the same conclusion.—AUTHORS.

The products of combustion were bubbled through water, and bromine added continuously by an automatic arrangement to oxidize the sulphurous acid. The exhauster, a Richards pump, used to draw the gases through the water, was insufficient in capacity and uncertain in its action, and, accordingly, only a small quantity of gas, from two-tenths to four-tenths of a foot, could be burned for each determination. A volumetric estimation of the sulphuric acid was then obtained by expelling the free bromine with heat and the hydrobromic acid by digestion with silver oxide, or, better, with silver carbonate. When this had settled, an aliquot portion of the supernatant liquid was withdrawn from titration, but as it was found to contain dissolved silver salts sufficient to obscure the reaction between hæmatoxylin or cochineal and an alkali, these were removed by precipitation with hydrogen sulphide, the excess of which was in turn expelled by boiling. The remaining free acid was titrated with standard alkali. In dealing with such small quantities the probable error was of course very large, and it was thought useless to make comparative experiments with the Letheby test until the apparatus should be put in condition to burn a larger quantity of gas for each determination. Before so amending, the whole process was abandoned in favor of the alkali test, and we have accordingly but one comparative experiment, No. 7. The general results afford some indication, however, of what might, under more favorable conditions, be accomplished with water as a scrubbing liquor.

Résumé.—In reviewing what has been accomplished, an advance in two directions seems possible:

First.—An apparatus has been devised for bringing gases into contact with a liquid, which is an improvement on bubbling them through the liquid contained in a Woulfe bottle in three respects. The necessity for an exhauster or blower is avoided, the gas is completely broken up, affording a more intimate contact, and the proportion of the two may be so regulated as not to flood the products.

Second.—The gas engineer is provided in this apparatus with a complete indicator of the working of all his purifying processes except the removal of the tar.

It is continuous. There is no instant of the day or night when the quantity of ammonia and sulphur passing into the holders or street mains is not being accurately measured.

It is ever ready, and if the condensers and scrubbers allow an abnormal quantity of ammonia to pass, or the purifying boxes become overworked, and there escapes traces of hydrogen sulphide, which

every engineer now intends to remove, the test-papers give immediate notice, and the amount of damage done can be quickly determined.

It is complete. The presence and quantity of ammonia, and of hydrogen sulphide and the other sulphur compounds are indicated, and the possible presence of carbon dioxide; for on account of the well-known power of that body to decompose moist calcium sulphide, setting hydrogen sulphide free, no noticeable quantity of carbon dioxide can pass the purifiers without the previous escape of hydrogen sulphide.

It is rapid. Ten minutes is ample time to determine both the ammonia and sulphur.

It is inexpensive. Fifteen dollars will provide all the glassware for the apparatus. The breakage is small, and the chemicals cost comparatively nothing.

Finally, it is simple in theory and practice. To work it successfully requires no knowledge of chemical theories, and the needful manipulations can be easily acquired by a little care and attention to a few simple directions.

AN OUTLINE OF ANTHRACITE COAL MINING IN SCHUYLKILL COUNTY, PA.

BY J. PRICE WETHERILL, TREMONT, SCHUYLKILL CO., PA.

THE coal-seams that are worked vary from $3\frac{1}{2}$ to 100 feet in thickness, and occur at all angles of inclination, but are never flat for any great extent. They contain coal, slate, and an unsolidified coal, called dirt by the miners, in various proportions, a uniform seam of coal alone being rare.

The upper walls are composed of conglomerate, sandstone, or slate; the first two hard and solid in texture, and withstanding the action of the atmosphere and moisture sufficiently well to offer but little trouble to the mining operations; while the latter crumbles rapidly, owing, in part, to the decomposition of iron pyrites which it contains in large quantities, and in part to its own friable character, and requires constant care to avoid accidents to the men working below it, and to prevent its mixing with the coal mined. The floors are composed of slate.

As in all mining operations, the general system pursued is to reach with a permanent outlet such a point in the seam as will

insure an amount of coal above the level of that point that will be profitable to work, and all the winning operations are carried on in that coal. By this means a natural drainage for the water is secured, and advantage is taken of the inclination of the seams to cause the coal to move by its own gravity wherever possible. The amount of coal that can be profitably worked is usually considered about 100 yards on the pitch of the seam, and not less than three-fourths of a mile on the strike of the seam; this is called one "lift." In some cases it is advantageous to develop more than one lift with the outlet. Where two lifts are desired, the distance will be two hundred yards on the dip; where three, 300 yards, etc.

The outlets are those passages by means of which access is obtained to the point in the seam at which it is desired to begin mining operations; they may be of four kinds.

1. The drift, which is a gallery or gangway driven from day in the seam, in the direction of the strike, and is only possible where ravines or gaps have cut mountain ranges containing coal strata. As the mining operations generally begin as soon as the drift has been driven into the solid measures, and as coal is the softest of all the strata in the formation, this is the cheapest method of developing a colliery. Another economy is in the fact that no pumping or hoisting machinery is required.

2. The tunnel, which is driven from day, at right angles to the strike of the measures, until the seam desired is reached.

3. The slope, which is sunk in the seam in the direction of the dip; the coal is hoisted through it, by machinery, to day.

4. The shaft, which is sunk vertically through the measures to the seam to be worked.

When the point desired is reached by the tunnel, slope, or shaft, two gangways are driven, one on each side, in the seam, and in the direction of the strike, as nearly level as will admit of the water draining readily to the outlet, where it is conveyed by suitable appliances to day. The usual grade is 4 to 6 inches in 100 feet.

The gangways are driven night and day continuously, and all the coal mined for 100 yards above them passes through them to the outlet. They vary in size with the thickness of seam worked. That shown in Fig. 1, Plate VII, is the one usually adopted in seams of 6 feet and over; while that given in Fig. 2 is the one used in smaller seams. Railroads are laid in them with T iron rails, 25 to 36 lbs. to the yard; 40 to 48 inches gauge in the larger; 30 to 36 inches gauge in the smaller. The coal is loaded into mine-cars, called

"wagons," which run on the roads, and contain in the larger about 100 cubic feet, and in the smaller 75 feet. Locomotives are preferred as the motive power in gangways, but as the exhaust-steam and gases produced by the furnace very seriously vitiate the air and complicate the ventilation, and there is great danger that the fire may cause explosions in mines producing fire-damp, their use is at present restricted to a few collieries possessing advantages in ventilation, and the motive power is generally supplied by mules. I am not aware of any instance of the use of the moving ropes or chains used in England for that purpose, or of any case in which the plan has been tested with us. As soon as the gangways have reached points where mining operations can be begun without endangering the stability of the outlet, the first breasts are started. They are excavations or chambers in which the coal is mined, driven of a uniform width at right angles to the strike, or directly up the pitch for 80 to 90 yards. A pillar of solid coal is left on each side of every breast, and running its entire length, to give solidity to the work and prevent a general crushing down of the top. The breasts are turned as fast as room is made for them in the gangway, and when the first is finished the men are moved forward to a new one.

Fig. 3 shows the arrangement of breasts, being a plan on the plane of the seam. The white portions indicate those from which the coal has been removed. B is the breast, P the pillar, A is a solid block of coal, called a "stump," left to sustain a great weight that would come on the gangway timbers if the breast were opened the full width from the gangway; the two small openings, *a a'*, answering every purpose as passages for the coal mined above to the wagon in the gangway, and for the men to get to and from the breast. They are called shutes, and are driven 4 feet high, 4 to 6 feet wide, timbered with 6-inch timber, and are given, where possible, an inclination that will permit the coal to descend by its own gravity to the wagons in the gangway. They are provided with a projecting apron that reaches out over the wagon, and a gate by which the coal can be held back until it is required.

In steep-pitching seams the coal mined at the face of the breast falls to the shute, and through it into the wagon by its own weight, is hauled to the outlet, and thence to day, and is never handled at all in the process of mining. The headings marked *c* are small passages 4 to 6 feet wide, 6 feet high, driven continuously like the gangways, and used for purposes of ventilation; the dotted line

across each breast shows its upper side previous to the removal of the coal and the opening of the breast. The breast headings, *d*, are also used for ventilation alone.

Fig. 4 is a side elevation of a shute—A is the stump, B the breast, S the shute. The floor is laid with 2-inch plank, and where the pitch requires, it is covered with sheet iron to allow the coal to slide over it more readily. C is the "battery"-prop; the entire shute being closed with plank, except an opening to allow the coal to pass through, which stopping is called the "battery." In steep pitches it must be strong enough to sustain the weight of loose coal above it.

Where the top rock is strong, it will not break down until there has been a great deal of coal excavated beneath it; but when it does start, the crush is much greater than it is where the top is weak and falls in short distances, before large excavations are made, filling up the vacant spaces with masses of rock, which act as supports. In the former case it may happen that the pressure will be so severe as to crush the coal when it is left standing for some distance, from the solid; a coal support, therefore, that is intended to confine a crush within certain limits, will require to be stronger where the top rock is strong than it will where this is weak.

As the gangways are the only channels for the coal to the outlet, they must be kept open at all hazards; and where the top is strong, the "stumps" or coal supports along them (A, Fig. 3) should be as large as economy will allow, say 10 to 15 yards; when the top is weak they may be only 7 to 10 yards.

The character of the top generally requires the breasts to be timbered (single timber or props, 6 inches diameter, being used), and where the pitch is great, the labor of conveying this timber from the gangway to the face of the breast, which must be done by hand, will limit the length of breast to that distance, beyond which it would be too costly an operation. On the other hand, when the pitch is so slight that the cost of carrying timber is much reduced, the coal mined must be pushed or "buggied" from the face of the breast to the gangway, as it will not descend by gravity, and the cost of this will limit the distance to which the breasts may be profitably driven. The length of breast in pitching seams found most convenient is about 80 yards, shutes included, but this is sometimes slightly varied.

The width of breast varies with the nature of the top and bottom; the stronger the top the wider the breast, but they are never driven less than 6 or more than 12 yards wide.

This statement apparently does not agree with the one above, that the stronger the top the stronger should be the coal supports; but the two cases are not similar. A breast need be kept open only while the coal is being mined in it, and when that is exhausted, it is of no further use, while a gangway must be kept open as long as any coal can be mined above it, and the distinction drawn is between a temporary and a permanent security. Another difference is, that when the top is bad and liable to fall in short distances, portions of the rock or slate may fall and mix with the coal mined in the breast, causing serious trouble to separate again; therefore, in the case of the breast, the excavations must be smaller, as compared with the strength of the support, than when the top is strong; while in the case of the gangway, the liability of the top to fall in short distances relieves the weight, and the coal supports need not be so large as where the top is strong.

Breasts are worked by the miners under either of two arrangements, according to the requirements of the seam:

1. "By the run," as it is called, where they receive a sum per lineal yard for driving a breast of a specified width, it being the duty of the mine boss to see that the proper width is maintained.

2. "By the wagon," where they receive a sum per wagon for properly cleaned coal, the width of breast and lineal distance not entering into the account.

Breasts are worked under the first arrangement only where the pitch is so great that the men working them cannot keep up to the face of the work without supports, or, in other words, where the pitch exceeds 40°.

Breasts worked by the run may be opened several ways: the most commonly used are illustrated in Figs. 5, 6, 7, and 8, Plates VII and VIII, which are plans in the plane of the seam.

In the plan shown in Fig. 5, which is the one most frequently used, four strong props (of 8-inch timber) are set at *a a* and *a′ a′*, just above the stump. Against these, two log batteries (*b b*) are built, in each of which an opening is left that will permit large lumps to pass through freely, say four feet square. The miner then starts his work, and the coal cut is allowed to fill the space excavated, just enough being drawn from the shutes to leave room at the face for him to work. It is, however, necessary to provide means by which air shall be supplied across the face of the breast, and this is done by keeping a small opening in each side of the breast, marked D, so that the air may ascend on one side, cross the face, and descend on

the other. The arrows indicate the course of the air. These openings are called manways, and are timbered in the manner shown, being made as near air-tight as possible, with 2-inch plank nailed against the upper side of the timbers. It will be observed that each timber is notched in the pillar to keep it in place. These timbers are called "jugglers," and are set four, five, or six feet apart, as may be most convenient for the men in carrying up the planks.

As the driving of the breast progresses, the manways are constructed, and should never be allowed to be more than six feet from the face. The great body of the coal is retained in the space marked "loose coal," until the distance is reached to which it may be desired to drive the breast, in order that the men may have a support to keep them up to the face on which they work. After that distance is reached, the coal is drawn from the openings in the log batteries, *b*, until it is exhausted. It will be observed in this method that in case any accident should happen by which one of the manways in a breast should be obstructed so as to prevent or very much lessen the circulation of the air at that point, all the breasts inside of it would be deprived of ventilation until it was repaired. This, in seams making much fire-damp, would be a most serious delay, and the plan shown in Fig. 6 is used to overcome this defect.

The breasts are started with only one shute, which is in the centre, instead of two, one on each side. At the heading, three strong props (*a*) are set to sustain a log battery, which may have one or two openings to draw the coal from as may be desired. The breast is gradually widened in the manner shown, until the full width is reached, the manways, D, being timbered and planked as in Fig. 5. At the centre (*a*) of the three props, a stopping is put in which turns the air up into the inside manway, and it is carried across the face and down the outside one, as shown by the arrows.

Should any accident obstruct either of them by opening the stopping, *a*, across the heading, the breast can be isolated and the current pass on to the next one, until the damage is repaired. The two manways, D, are made to diverge from a single shute, in order that the excess of loose coal over that necessary to keep the men at the face may all be delivered at the bottom through them into the shute if necessary. It is necessary to draw the excess of coal from the manways, instead of the breasts, when the top or bottom is bad, or both, because: 1st. The jugglers being notched into a soft material, are liable to become unseated by the moving mass of coal, and as it is necessary that the excess should be removed every day as fast as it

is made, repairs would be required to the manways daily, and this while the miners were at work in the breast. 2d. There is less liability for the moving mass of coal to rub off or dislodge portions of the top or bottom if the mass of coal lies perfectly quiet until the breast is finished, and then is drawn out as rapidly as possible, than there is if it is moved a little each day; and should the jugglers become unseated after the breast is finished, and the men are out of it, no difficulty arises, as ventilation is no longer required in the breast.

As the single shute is always more or less full of coal, a manway is driven from the gangway to the heading between each two breasts, and is used by the men working as a travelling-way both to and from their work.

Fig. 7 shows a plan in which an additional stump, A, is left to keep open the heading which is continued across the breast. The stopping, *a*, in the heading, opposite the centre of the breast, if removed, would isolate the breast in case of accident, as above. As this coal can all be taken eventually, there is no loss in pursuing this course.

Fig. 8, Plate VIII, shows a system pursued in thick seams sometimes, where large quantities of gas are made. I have shown the gangway as driven against the top, which is sometimes done to give greater security to the gangway. The main feature of the plan is an air-course, *c*, driven against the top above the gangway, and connected with the manways, E E, between each breast, by the passages, F F. When the breasts are in operation the air-course, *c*, called a "monkey gangway," is not used, the arrows in black indicating the course of the air; but when it is necessary to repair one of the manways, D D, the course is shown by dotted arrows. The great advantage it has is in securing a permanent return for the air after the breasts are exhausted. It is, however, more expensive, as there is more narrow work to drive.

The coal made along the manways, D, may be drawn from the manways, E. The main shute, marked "coal shute," is driven large (9 feet wide), and has a travelling-way in one side to allow a man to attend to the drawing of the coal.

In many cases all the coal in excess of what is necessary to keep the men up to the face is drawn from the breast shutes, and not from the manways, in order—1st. That the manways may not become obstructed; 2d. That the coal in falling in steep pitches may not be broken. Where this coal is thus drawn, it is desirable to draw from a centre shute, instead of two side shutes, as there is a tendency in

moving the coal along the manways to unseat the jugglers, which may be partially overcome by driving a third coal-shute between the two shown in Figs. 5 and 7. and drawing the excess of coal from it. This has a tendency to allow the coal along the manways and against the sides to remain at rest while the motion takes place down the centre of the breast. In all places where the bottom is bad, and the breast requires to be emptied as soon possible after it is finished; as three shutes are a great advantage, as three times as much coal can be loaded from them in the same space of time as there can from one.

It will be seen that in all plans of working by the run there is no opportunity to leave in the breast any of the impurities contained in the seam ; everything must be taken out with the coal. As shown in the sections, Fig. 9, the amount of unprofitable material necessary to move in some cases is excessive. Since the breast must remain full of loose coal until it is driven to its destination, there is always a liability of portions of the top or bottom becoming detached and adding to the impurities, and in some cases these causes operate so seriously against working by the run that it is impossible to use the plan.

When the impurities are so great that they fill up the space marked "loose coal" in Figs. 5, 6, 7, and 8, so as to keep the men up to the face of the breast, the good coal may be thrown down the manways, and the breast worked in that way until it is finished. If there are not enough impurities to do this, breasts on steep pitches are worked "on batteries," as it is called, where the thickness of the seam is not so great that it cannot be timbered. When the seam is over 12 feet, and so impure that it cannot be worked by the run, it is not possible to work it at all; 12 feet, and under 12 feet, may be worked on batteries.

Fig. 10 illustrates the course pursued. Rows of props of 6 to 8-inch timber are set across the breast every 15 to 20 feet up the pitch as it progresses, and a few planks nailed on them, making a platform on which the men stand to carry on the work. Two manways are kept open, as in the former method, for ventilation; but it is only necessary that the inside one, or the one delivering the air at the face, should be made air-tight. As the coal is mined it falls upon the platform, and the good coal is separated from the refuse and thrown down the manways, the refuse being thrown into the breast, where it remains, occupying the space marked "loose coal" in the previous figures, and is called the "gob." Breasts worked "on batteries" are

worked by the wagon. Care must be exercised, as far as practicable, to keep the jugglers and planking covered with the gob, in order that any falling portions from the top, or elsewhere, may have the force of the blow deadened, so as not to break them down, which would not only obstruct the air, but also cause the impurities in the gob to mix with whatever coal was in the manway at the time.

Where the pitch of the seam is from 12° to 40°, breasts are worked in the same manner as on batteries, except that the platforms or batteries are not necessary, as the men can keep up to the face without assistance. In all such breasts, the central space, marked "loose coal," Figs. 5, 6, and 7, is used to retain the waste matter or gob, and the good coal is invariably sent down the manways. There is an unavoidable waste in the passage from the face of the breast, caused by the lumps grinding together, which would be lessened if the manways could be kept full, but this cannot be done, because it would retard or obstruct the ventilation. The waste is not, however, as great as in the cases shown above, where the pitch is steeper. All breasts in these pitches are worked by the wagon, the coal that is produced each day being removed at once, and a great advantage is thereby secured over breasts worked by the run, where the coal cut must remain in the breast until it is finished, in that the liability of portions of the top or bottom to be detached and mixed with the coal is entirely removed.

From 12° to 28° the manways must have sheet iron laid on the bottom, as the coal will not slide on the irregular bottom of the seam, and in the lighter of these pitches, say 12° to 20°, it must be pushed by hand down on the sheet iron.

From 6° to 12° of pitch are worked with "buggies," which are small wagons running on a track, and pushed up to the face, loaded, and lowered to the gangway, as required. They do not generally hold quite a ton, and sometimes only half a ton. The rails may be of iron or wood, the latter being preferred in the steeper pitches, because there is greater friction between it and the wheels, and the loaded buggy is easier to handle.

The coal is dumped on a platform, from which it is loaded into the wagons in the gangway with shovels. Fig. 11 shows the arrangement. As much room is secured in the dump as the top will allow in order that the platform may hold as much coal as possible without additional handling, so that the miners may be enabled to continue their work should any accident cause delay to the gangway wagons, and consequently prevent the removal of the coal on the

platform for a few hours. Buggy breasts are always driven with single shute, and the refuse thrown to one side out of the way of the road.

When the pitch is flat to 6° the wagons are taken directly into the face and loaded there. Such breasts are called wagon breasts, and are turned with single shutes, not at right angles to the gangway, except where the pitch is flat. Fig. 12 shows the arrangement. As before stated, the gangway rises at a grade sufficient to secure drainage to the outlet, and each breast is also usually driven at such a grade as will permit the loaded wagon to descend by gravity, so that after it has been hauled empty to the face it is not necessary for the driver to return with a mule for it, thus saving time and labor. Furthermore, the nearer a breast can be driven directly up the pitch, the greater strength will be given to the pillars, and it is therefore desirable to drive the breast as near in that direction as will allow the mule to haul an empty wagon to the face. An advantage in overcoming these grades is obviously gained by turning the breasts towards the outlet, as shown in the figure, instead of away from it, which would appear to be the most natural direction for them to take.

Where the top is bad, the road is laid along one of the pillars to gain greater security, and the refuse or gob matter is thrown to one side out of the way of the road. Wagon breasts are frequently driven to much greater distances than any of the others, as the objections to doing so that were valid in their cases do not exist here, the timbers being hauled in in the wagons, and the coal hauled out.

Where the seam is of great thickness, slight pitch, and a bad top, a large shute is sometimes driven on the bottom slate, up the centre of the breast, to the distance at which it is desired to drive the breast, and timbered with 8 to 10-inch timber. Mining is then begun at the top of the shute, which is opened out at that point to the full width of the breast, and the coal is worked back to the stump heading, the good coal being sent down the shute to the gangway and the top allowed to fall behind the face. Of course, on such pitches as would permit the impurities to crowd down into the shute, this plan cannot be pursued.

I have heard of breasts in thin seams being worked in this manner, but as the expense of driving the shute is considerable, the amount of coal obtained in a thin seam in one breast would scarcely repay the outlay at present prices.

Although many plans of working breasts are followed, I think those here shown will give the most common ones, as well as those most profitable, and the variations are not essential. I have purposely left out the method called "panel workings," as it is as yet but an experiment, and has not been adopted in practice with us.

It is usually customary to open and work the breasts on the gangways as they are driven, so that shortly after the gangway has reached the point to which it is desired to drive it, the breasts are all finished. Whatever coal it may be possible to obtain from the pillars, is then taken out, beginning with the last breast and robbing out to the outlet. It frequently occurs that this system of working out the breasts as the gangways progress, so weakens the supports to the top as to bring on very serious crushes. Sometimes it is possible to meet this difficulty by setting new timbers in the gangways, but in some cases the gangways have been abandoned at serious loss. Benefiting by an experience so gained, there are collieries in which the gangways are first driven to the limit before any breasts are opened; then work is begun at the inside of the gangway, as many breasts being worked at a time as the capacity of the preparing apparatus requires; say, where two gangways only are driven, 10 to 15 breasts in each, and the pillars are robbed there, and all the coal obtained that is possible before opening breasts in another section.

As the gangways, shutes, and headings, or "narrow work," as they are called, in general do not pay for the expense of driving, such an operation requires a large outlay of capital before any return is obtained, and is only within the reach of the wealthiest operators.

Another plan that has been successfully used, is to leave, at stated distances, barrier-pillars of sufficient thickness to sustain the top, and prevent a crush extending beyond them, working out the coal between as the gangways progress, but leaving in the gangway stumps. As the plan is not yet in general use, I cannot give the exact distances of section and barrier-pillar best adjusted to economical working and stability; the usual irregularity in size and condition of the seam also enters largely into the question (places where it is thin, or of poorer quality, are selected for barrier-pillars), as do also the character and ordinary behavior of the top. In the future, as the amount of exhausted territory above the ground in the process of mining increases, it is probable that our system of working will require to be modified to meet the requirements of the case.

Gangways are driven as far as economical working will allow, or until some natural boundary, such as an anticlinal or synclinal axis,

where the seam is in fault, is reached, or a fault too large to drive through profitably. The limit to which a gangway may be driven will depend more upon the condition and size of the seam, and the character of its upper wall than upon the mere distance to move the coal. In other words, the cost of keeping open a gangway will limit the distance to which it may be driven, natural boundaries excluded. Where seams are thin, and contain strong coal to keep gangway stumps intact, with good slate or rock top, the cost of repairs necessary to keep gangways open will not be large, and they may be driven for two or even three miles profitably. But in large seams, even under the most favorable circumstances, one to one and a half miles will be all that can be maintained with advantage, and where the conditions are unfavorable, half a mile will be ample. Since the coal lands have become the property of large and wealthy companies, much of the evil that necessarily arises from property restrictions on the natural location and extent of collieries has been done away with, and improvements are now perpetuated by giving them all the coal within their natural scope, irrespective of property limits. The tendency therefore is to diminish the number of collieries hitherto in operation, and increase the capacity of those advantageously located; and greater lengths of gangways, improved methods of keeping them open, and increased facilities for mining coal to greater distances are among the requirements of the future.

It sometimes happens that it is desired to locate the lower terminus of the outlet at such a level as will give two or more lifts above it, or the dip of the seam may become so much flatter as, in the same vertical height, to give much greater length of breast on the dip. Assuming the dip at the outlet to be 60°, and that in one of the gangways it flattens to 30°, the length of lift which was 100 yards at 60° will be obviously very much increased beyond the distance that can be profitably worked from the gangway. Under these circumstances it is customary to lay tracks in one of the breasts after it is finished, and convert it into an inclined plane, which is operated by gravity, the loaded wagon hoisting the empty one,—all the machinery consisting of a drum, on and off which the ropes are wound, and a brake to regulate the speed. Gangways are driven from the top of the plane, similar to those described above, and the same course of mining is pursued. The steepest inclination I have known a gravity plane operated on is $37\frac{1}{2}°$ (although with competent brake there is no reason why this should not be increased), and the slightest is 5°.

In cases where the pitch is too steep for a plane, or where the expense of one is not desired, the coal from the upper gangway is dumped into an empty breast and loaded therefrom into wagons on the gangway below. Such a breast is called a "counter-shute," and the upper gangway a "counter-gangway." Since there is no provision in the counter-shute plan for getting up the timbers necessary from the lower gangway, they are sometimes put off the wagons on the outlet (if a slope) at that level, and if this cannot be done, they must be either lowered from the surface or hoisted from the bottom level by hand. Where the dip is not so steep that it will take harm from the speed at which it travels, it may be allowed to slide down an airway or some suitable opening; or if the dip is too steep, a small plane with 2½ to 3 feet gauge may be laid in the opening, and the timber lowered by gravity on trucks made for the purpose. Where neither of these appliances are used, the timber and rails must be either hoisted by hand with a windlass, or carried by men up to the counter-gangways, and the wagons must also be taken to pieces and carried up, all of which adds to the cost of the counter coal, besides the unavoidable waste there is from the tendency to grind into dust in the passage from one gangway to the other in the shute. The latter evil is in part obviated by keeping the shute constantly full, so that the velocity and consequent loss of the moving mass is reduced to a minimum.

It will be observed that in the system of mining pursued with us, the direction of the "cleat" does not influence the course in which the breasts are driven—as it does in bituminous coal mining; and the reason is that our steep angles of inclination do not admit of any variation of the rule laid down above in working breasts, within any practicable limit of economy. Furthermore, since anthracite is so hard as to require the use of powder, in almost every case the benefit derived from the cleat is not as great as in softer coals requiring little, if any, blasting. However, our miners always take what advantage they can in locating and charging their shots with reference to it.

When the gangways have been robbed back to within as close a distance to the outlet as is deemed safe for its stability, the work is finished at that level, and the gangways need not be kept open unless they are to be used as water or air-courses. It is always desirable to keep the water produced at each level at that level, and not permit it to go lower, making thereby less work for the pumping apparatus to do; and it is therefore generally necessary to keep old gangways

open as water-courses, where possible. I have myself considerable doubts as to whether in thick seams the amount of coal lost in the endeavor to keep up water at different levels, which is not generally successful for more than a very few years, is not an unnecessary and extravagant waste at all levels except the water level.

After the one or two lifts, as the case may be, that have been developed by the outlet are exhausted, it is continued to another lift, or more, as may be desired, when the same course of mining is pursued.

Fig. 14 is a plan on the plane of a seam, and shows the method pursued in sinking the outlet (assumed to be a slope) for new developments, with regard to the amount of coal left to sustain the old level and the ground taken for the new.

Very generally over and underlying seams are developed and worked by tunnelling from the seam on which the outlet is located.

The dimensions of the tunnel are usually 7 feet high, clear of the rail, and 10 feet wide, which will admit of a brattice and air-course while under construction, and afterwards if necessary, and competent drain for the water. (See Fig. 13.) Unless the distances are unusually great, these tunnels are driven by hand, as air-compressing machinery necessary to drive rock drills is not generally used at the collieries for other purposes, and the expense of putting it up for tunnelling alone would so much increase the cost of the work as to overbalance the advantage in time saved.

When we consider that the loss under this system of mining is not less than 30 per cent. of the amount of coal in the seam, and in many cases exceeds 50 per cent., it is evident that it is still very far from perfect. What developments of science may in the future be utilized to reduce this loss we do not know, but as it is chiefly due to the great thickness and steep pitches of the seams, I expect that the difficulty will be overcome as successfully as many others have been. It must further be borne in mind that the mining of anthracite coal in this country, under the direction of educated men, is as yet in its infancy, and the abundance of the article has restricted their improvements within well-defined limits as to cost.

I have not entered upon the subject of ventilation, as it would lead me to greater lengths than I had contemplated in this sketch, and the system does not differ from that pursued in other mining enterprises, save only in its complexity.

Mr. Coxe.—When the loading is done by the wagon, are the men paid so much a wagon for the coal and so much a wagon for the slate, or do you load them altogether and separate them on the surface?

Mr. Wetherill.—When breasts are worked by the wagon we pay a certain sum per wagon for properly prepared coal.

Mr. Coxe.—I mean where they are worked by the run.

Mr. Wetherill.—When they are worked by the run we have to take everything that is mined in the breast.

Mr. Coxe.—Do you never have a double shute and throw the slate on one side until you get a carload of it and then haul it out?

Mr. Wetherill.—I think there may be a partition in the shute in many cases.

Mr. Coxe.—If that is done, is the miner paid so much a car for the coal and nothing for the slate, or so much a car for the coal and so much for the slate?

Mr. Wetherill.—When he works the breast by the run, he doesn't get anything at all by the wagon.

Mr. Coxe.—I mean the loader. When we work by the run in steep breasts we put in two shutes and endeavor to have room enough in one shute for a man to collect a carload of slate. I have been informed that in some places in Schuylkill County they pay a man the same price for a carload of slate as they do for a carload of coal. If there is coal in the slate, they dock him for coal; if there is slate in the coal, they dock him for slate; this offers no inducement for the man to put the slate with the coal or the coal with the slate, for he gets the same price for loading coal and slate. After the cars come out the slate is inspected and the coal is inspected. If he puts coal with slate he is docked, and if he puts slate with coal he is also docked. In other words, his interests become exactly the interests of the proprietor. I would like to know whether that system exists. I have been told that it does, but I never could get any definite information as to where it was employed.

Mr. Wetherill.—It is not done by us.

Mr. Coxe.—It seems to me to be the true principle, and I would like to find out about it. It is a great deal easier to adopt a thing of that kind if you can tell your men that it is done somewhere else, and as I have some breasts to work on the run next year I would like to know.

Mr. Symons.—There are places where the coal is separated from the slate in shutes. I have no knowledge how it is paid for.

Mr. Coxe.—We have never paid the miner for the slate, and the question is whether a much better result would not be accomplished if the loader was paid equally for both coal and slate, because the labor is the same or greater in loading a car of slate as in loading a car of coal.

Mr. Rothwell.—Mr. Wetherill mentioned that he was not aware of any place in this country where the underground haulage by fixed engines was in use. I was in one of the mines of Gray & Bell at Pittsburgh where they were using the tail-rope system, and they told me with great success, and that it was much more economical than hauling by mules. I believe there are one or two other mines there that have also the tail-rope system in use. I wish to ask Mr. Wetherill a question with regard to the waste in mining by these different systems: whether in his practice he has been able to ascertain what is the difference in waste inside in pillars and incidental waste in working by the different systems. Some years ago I had an opportunity to examine pretty carefully the question of working by the run on very steep pitches in the Lehigh region near Mauch Chunk. The veins there were in some places nearly vertical, and the coal was occasionally so soft that it would commence to run in the breasts of moderate width without any mining. The coal would come down, and it was drawn as long as any came, or until the roof rock came down in such quantities that it would not pay to take it out in order to get what coal might remain. Of course the waste was enormous. Calculating over a large area that had been worked in a great number of years, I was not able to find that the company had got more than 30 per cent. of the coal in the veins. When I say this I mean that it marketed not more than thirty per cent. There was a certain amount that came up from the mine and was finally dumped on the dirt bank and lost there, but the greater part of the loss was inside in the pillars. In this system of working by the run, where the coal was soft and commenced to run, there was no knowing how much or how little was left in. I would like to know whether in Mr. Wetherill's experience he has been able to calculate whether there was any difference in these different systems of working, and if he has any figures to indicate what amount of loss there was in the mining under each.

Mr. Wetherill.—I have no figures by which I could indicate the amount of loss in mining. In the selection of a system to be pursued at a colliery we are controlled by the pitch, and have but very little choice. Undoubtedly a breast that can be worked by

the wagon possesses a great advantage over one worked by the run, because there is not the liability of the coal becoming mixed with impurities by remaining long in the breast. As it is mined every day it is sent down and taken out; I cannot therefore compare one breast with another, or one worked on one system with one worked on another system; and unless we can do that, the inequalities in the character of the vein are so great that I do not see how we can get at any reliable result.

MR. ROTHWELL.—It is not so much a comparison of the loss resulting from the different systems that I am after as the actual figures of loss under those different systems.

MR. WETHERILL.—I have no actual figures.

MR. COXE.—I had occasion one time to make a calculation of the amount of coal taken out of a large property; I think it amounted to something over a million tons. I happened to have a pretty careful survey of the property, and the area of the ground worked over. The thickness of the vein was pretty well determined. I was not able to measure it myself. I had been in the vein, but I took the thickness as given to me by the engineer, one of our members, and a thoroughly reliable man. My calculation showed that, assuming the specific gravity of the coal to be about 1.55, and calculating the cubic contents of the vein under the surface that was considered worked out, the coal actually sold was about 28 per cent. of the theoretical amount of that in the vein. Part of the loss was in the pillars, part in overweight (when coal goes over the scale of the company the exact weight is not recorded, for we are obliged to give a certain amount to make up for loss while being transported), and part represented coal burned at the collieries (by the men and for the purpose of making steam; this is not accounted for in the tonnage). There are also squeezes and faults which you cannot take into account in calculating, and you have to assume that the whole area is about the average thickness of the vein. This makes the calculated yield too great. There is also a very large amount of loss in the preparation. The seam was nearly 10 yards thick, and I think that there are many veins of this size that do not average as much as 28 per cent.; yet there are some that average more. I think that from 28 to 30 per cent. is perhaps as high as the average mines in the Mammoth vein yield.

MR. HEINRICH.—It is quite evident that the system of mining which you pursue in the anthracite region is very profitable, opening mines very rapidily; but it is also evident, if you look observ-

antly, that an enormous loss occurs, and I don't see how in the world it can ever be profitable in the future unless you change your system. It is evident that you have an enormous loss which you cannot prevent with the means with which you are now working. I suppose you have a very firm roof and your timbers may stand. If your roof is weak at all, it is bound to give way in your openings with narrow pillars before you get to the end of the mine. You will have an enormous amount of rubbish left in there, and you will, in consequence, either not be able to remove the pillars at all, or if you do remove them, you have then to move all the rubbish. That is the natural consequence of the system by which you work.

If a modification of the panel system could be adopted, you would do better, I think; but of course the panel system will never allow you to open mines as rapidily as you open your anthracite mines. Looking over the history of the anthracite region you will see that the mines have been developed most wonderfully in a very short space of time; far more so than in the bituminous coal regions. But, gentlemen, the question will arise when the bituminous coal interests of the United States begin to climb up—your rival hereafter—if you had not better husband your enormous resources of anthracite (which nevertheless is limited in quantity) by economizing now, for by going on with your present ruinous system, the anthracite will be exhausted in the course of a comparatively short time, and your rival will be far ahead of you in production. The amount of bituminous coal in this country cannot be calculated at all; it is beyond human figures, you may almost say, while your precious anthracite can, I think, be pretty accurately calculated.

If you refuse to do now, what at least all well-regulated mines in Europe do, that is, to produce at least two-thirds of your coal,—and many of them in the thicker veins even more than that,—then you will waste a great deal of your natural wealth.

Mr. Wetherill.—I do not think there is an engineer in the anthracite coal-field who will undertake to defend the system pursued at present, or has any idea that it cannot be very much improved.

Mr. Rothwell.—Was there not an attempt made to work by the long-wall system at the Colorado colliery in Schuylkill County?

Mr. Wetherill.—That was the panel system.

Mr. Raymond.—I believe, Mr. President, that it is the theory of our present system that after the extremity of the gangway has been driven to the boundary, whether the natural or property

boundary, that we should rob the pillars in returning, and get out the coal that is in them.

We know that in practice for many reasons it turns out otherwise. Very often in my experience in a colliery which we are working near Pottsville we have lost pillars, not because the coal was crushed or destroyed, but because by careless and cheap working on the part of previous tenants, gangways were destroyed, so that really we were cut out of large areas of coal by that reason, and it would be some time perhaps before, by other operations, we could come safely into that coal.

But the point I wish to make is, that where we are prevented from working back on the coal in the pillars by the destruction through pressure and falling of the roof, and the crushing of the coal in the pillars themselves, I wish to ask Mr. Wetherill what he thinks would be the result if the plan which has been followed in some cases of breast and pillar-working, and which has been strongly recommended, should be pursued, viz.: instead of making the breast wider than the pillars, as they are shown here, in the proportion of not quite perhaps two-thirds breast and one-third pillar, reversing that tradition and making narrower breasts and wider pillars, so that the coal will stand in the pillars. Now I conceive that it would be economical to adopt a compromise between running to the gangway boundary and working backwards, robbing the pillars as we go (to adopt which requires, as Mr. Wetherill has said, a great deal of capital), and the present system, which is to take out just as much coal quickly as you can, leaving a third or more standing, in the hope that you will get it; for when you leave so little you don't get any, whereas if you left more, possibly you might get all.

Mr. Coxe.—I have often thought that I would adopt very much what Mr. Raymond suggests, and that is to drive up narrow breasts. Then when you get to the line you can begin and you would have say 20 to 24 yard pillars and 10 yard breasts. Take then the last ten pillars and drive breasts up in them; rob those pillars in coming back and let that all crush in; I think a series of 24 yard pillars would enable one to do this. Then start and take 10 yards more, which is very much as Mr. Wetherill suggested. I suppose you could do it by driving four shifts. I entirely agree with Mr. Wetherill with regard to the absolute uselessness of attempting to keep up the water. I would let all the water go to the bottom, because the amount you stop here is very little, and it is very liable to come down and drown you out when you don't want it.

Mr. Harden.—I would call the attention of the members to some work being done at Longdale, W. Va., where a seam four feet thick is being mined with chambers about 30 feet wide and pillars about 100 feet, and a section of the seam is being taken out to a distance of perhaps a thousand feet, and then returning, all the coal is taken out. I think Mr. Firmstone will corroborate that.

Mr. Firmstone.—Yes, I believe they have succeeded so far in getting all their coal. They have not lost any pillars yet, and have robbed a considerable portion of the mine successfully, and from all the indications they will be able to go on successfully. That, however, is a bituminous coal mine, and lies nearly horizontally, is about four feet thick, and has a very heavy massive sandstone roof, but in spite of the heavy roof they have succeeded in getting the pillars without any trouble at all. The roof breaks in very large lumps, I suppose 10 and 12 feet cube. I have looked into the part of the mine that was being robbed, and not being accustomed to such things, it was to me a rather frightful sight.

Mr. Harden.—In my examination I found they were withdrawing pillars very successfully, that the roof had come down in very large masses, about 30, 40, or 50 feet, and in some cases it had broken down right up to the face of the pillar, and I was told that they had been obliged to leave one small stump of a pillar in order to recover themselves.

Mr. Firmstone.—Yes; they did lose that, I believe.

Mr. Wetherill.—It was asked whether it would not be better to drive breasts narrower and let the pillars be larger. If you drove the breasts much narrower they would be classed as narrow work, which is the main expense in a colliery, and you would reduce the profitable yield.

Mr. Raymond.—I do not mean to drive the breasts narrower, but to reverse the relation.

Mr. Wetherill.—I believe it would be better to adopt Mr. Coxe's plan and leave every other breast.

Mr. Symons said he had adopted the plan of driving two breasts for better ventilation, leaving a large pillar between the next two.

Mr. Raymond.—A paper was read at one of our meetings by Mr. Heinrich in relation to steep pitching anthracite veins and the method of mining them, etc. I think he went so far as to say that when the slate in our seam was not sufficient to form a gob, we could practically and economically carry stuff in to fill up. I understood him to say that he either had done or was intending to do it

at his own colliery; to take material below when the vein did not yield enough.

MR. HEINRICH.—I have adopted a similar plan to what has been spoken of. I am driving two headings, and leave pillars, and only drive one heading between the pillars. Of course I am compelled to narrow my gangways or my headings to still greater limits than you probably are in the anthracite region, because my roof is frequently a very bad one. I am driving headings not more than three or four yards, and I leave pillars not less than twenty-two yards. That I am doing at present for the simple reason that my object is to press forward as fast as possible, leaving at the same time my resources behind to employ more men whenever it is necessary. But at the same time I am a strong advocate of the view expressed by Mr. Coxe, to work two such breasts and leave larger pillars between; because you may be able between two of these headings to preserve your pillars with large pillars on each side and successfully rob when you come back. The two pillars on each side will help to support the small pillars between.

As for transporting the rest of the stuff into the mine, Mr. Heinrich thought that under certain circumstances it was quite practicable, and he described the manner in which he had done it at his (Midlothian) colliery in Virginia.

MR. RAYMOND.—It has occurred to me that our principal expense and trouble of lifting things out of the mine certainly ought not to be an argument against any proposed method of mining that involves putting something in it, because it is the easiest thing in the world to let anything go down; our trouble is to make it come up.

NOTES ON THE METHOD OF PREPARATION OF ZINC OXIDE.

BY PROF. CHARLES P. WILLIAMS, PH.D., ROLLA, MISSOURI.

THE successful production of zinc white or oxide on a commercial scale in this country dates from the issue of the patent of Samuel Wetherill, for the preparation of the material (November, 1855), and

from the earlier patent of Samuel T. Jones, for the mode of collection. In Wetherill's method the furnace is an arched chamber, of rectangular horizontal section, the sole of which is composed of perforated grate-bars. The closed space or chamber beneath the sole is supplied, by a fan blower, with the air requisite for the combustion. The arched roof is pierced with two openings, the one connecting with the stack, the other communicating with the collecting apparatus. At different stages of the operation the one or the other of these openings is kept closed.

The furnace is operated by spreading over the grate-bars a layer of anthracite coal (commonly of the size of either "pea" or "nut" coal), which, after thorough ignition, is covered with a stratum of mixed crushed ore and anthracite dust, in the proportion of two parts by weight of the former to one of the latter. The usual charge is about 600 pounds of the mixture indicated; the weight of the bedding coal is from 250 to 300 pounds. The charge is elaborated in about six hours' time.

In this furnace, under the conditions indicated, there is a rapid reduction of the zinc oxide of the ore to vapor, and an almost simultaneous reconversion of the metallic vapor into oxide. This reduction and oxidation of the zinc, taking place *pari passu*, as it were, in the same furnace chamber, constitutes one of the interesting features of the method, which Wetherill notes, in describing his furnace, as "a compound reducing and oxidizing furnace."

The residue, withdrawn from the grate-bars after the elaboration of a charge, consists, beside some oxide of zinc, of the ashes of the reducing and bed coals, unconsumed coal, and the non-volatile matters of the ore, and is entirely scoriaceous in character. Its weight is about equal to the weight of the ore in the charge, or, say, about four hundred pounds. When the furnace has been properly charged and worked, the amount of zinc oxide remaining in the residue ranges between 2½ and 4½ per cent. of the weight, with probably about 3 per cent. as the average content of the normal residue.

Experience with these furnaces has shown that increase in amount of zinc oxide in the residue invariably follows increase in the thickness of the charge, and that no lengthening of the time of treatment will serve to remove this oxide. In the annexed table (which is condensed from the testimony in *Wetherill et al.* v. *The New Jersey Zinc Company*—United States Circuit Court, District of New Jersey, 1871) there are collected some analytical results bearing on this point:

No.	Depth on sole (inches).	Time of work (hours).	Zinc oxide in residue (per cent.)	Analyst.	Remarks
I	5 to 7	6	(under) 4	Roepper	Average at "Lehigh Works"
II	5 " 7	6	2.5 to 4		" " "New Jersey."
III	6 " 8	5	2.03	Garrett.	New Jersey, regular.
IV	6 " 8	6	1.20	Williams.	" " "
V	14 " 17	13½	8.05	Roepper.	" " experiment.
VI	16 " 19	28	10.45	Williams	" " "
VII	16 " 19	28	13.05	Roepper.	" " "
VIII	16	28	10.23	Williams.	New Jersey, experiment with alternate layers coal and charge.
IX	10 " 11	14	9.75 10.54 8.06	Roepper Williams. Garrett	New Jersey, experiment.

It would seem from these results that the best returns of oxide are obtained with a depth of about six inches, measured from the grate-bars, and including therefore the thickness of the bed coal layer. Much less thickness than this is not practically attainable without a decrease in the duty of the furnace, which would scarcely be compensated for by the slight gain in oxide from a cleaner residue, it probably being more economical to allow a wastage of oxide to the amount given than to decrease the production of the establishment by lessening the weight of ore treated.

As the depth above the sole is increased, the wastage of zinc oxide becomes greater, till, as shown above, with a thickness of somewhat more than sixteen inches, a working period of twenty-eight hours gave a residue with 13 per cent. oxide. Alternating layers of the bed coal with the mixed ore and coal gave no noteworthy decrease in the amount of zinc oxide left in the residue.

If the relations of zinc to carbonic acid at certain elevated temperatures be considered, these results, as well as the peculiarities of the furnace, are readily explained. Such relations impress on zinc metallurgy peculiar features; for besides provisions for the reduction and volatilization of the metal, they necessitate such peculiarities in the condensation that the receiver must be much smaller than the retort (in practice about the proportion of one of receiver to sixteen of the retort) in order to lessen loss by reconversion of zinc vapor into zinc oxide.

In the manufacture of zinc oxide, where reconversion to the fullest extent is desired, the upper part of the furnace above the charge takes the place of the receiver, and is, therefore, larger than the distilling apparatus or space occupied by the charge. It is admitted that the oxidizing agent is carbonic acid, for, from the conditions of the working, atmospheric oxygen must be almost entirely wanting;

besides, oxidation effected by oxygen admitted above the charge is only partial, giving "blue powder"—a mixture of zinc metal and oxide. Carbonic oxide must be the effective reducing agent, for the mixture of ore and coal is hardly intimate enough for solid carbon to have much effect in deoxidizing the oxide of zinc of the ore. Under such conditions the series of reactions in the furnace may be taken to be somewhat as under:

1. Production of carbonic acid by combustion of bed coal.

2. Reduction of carbonic acid to carbonic oxide by carbon of the charge.

3. Reoxidation of carbonic oxide into carbonic acid by the oxygen of the zinc oxide of the ore, and volatilization of the zinc vapor at the temperature of these charges.

4. Zinc vapor + carbonic acid at the surface of the charge = zinc oxide + carbonic oxide, as final products.

With depth of charge increased above a certain limit, it can be understood that the temperature in the upper part of the bed would not be sufficiently high for No. 3 of the series to be brought about, or even for the final change. Thickening of the bed coal might cause reaction No. 2 to take place by the carbon of the fuel, with reduction of calorific power before reaching the charge.

If these are the changes in the furnace used for zinc white production, they do not differ in kind from those in spelter manufacture. In the former, however, reoxidation is courted, while it is reduced as much as possible in the treatment for metal.

If the ores contain sulphides in admixture, zinc sulphate is always found in the "oxide." The presence of galenite in the ore gives lead sulphate in the product. The ore of Sinking Valley, Pennsylvania, treated at the Keystone Works, contained, commonly, 6 to 8 per cent. galenite, and gave an oxide with 25.084 per cent. lead sulphate, 73.246 zinc oxide, and 0.574 zinc sulphate. The so-called Bartlett White Lead, formerly prepared from blende from the buddles of the Washington Mine (N. C.), with about the same amount of galenite, had 72.083 per cent. zinc oxide, 23.968 of lead sulphate, and 0.810 zinc sulphate.* It is probable that some of the lead sulphate is carried forward by the light zinc oxide; possibly, however, there may be a volatilization of metallic lead and a subsequent union with sulphuric acid and oxygen at reduced temperature. The

* The full analyses of these and other similar products, by the writer, can be found in Second Supplement to Watt's Dictionary of Chemistry, page 725.

latter action must come into play where nearly pure galenite is burned (into lead sulphate, mainly) as a substitute for white lead.

At Hopewell, Washington County, Missouri, the manufacture of oxide was attempted, at first by the use of charcoal, both for fuel and for reducing, but the color of the oxide was found to be impaired, so that change was made to anthracite. The latter was not abundant or cheap, while the ores were of high grade and relatively low in price. Probably with a view to adapting the manufacture to the economical surroundings, the charges of the furnaces were made somewhat heavier, the time of working was shortened, and less bed coal was used. These changes resulted in the production of "oxide" of good quality, though the resulting residue was rich in zinc. How far, if at all, this wastage was instrumental in the suspension of the work at the furnaces, I am not prepared to say.

There are eight of these furnaces at the works named, each with a horizontal section of 6 by 4½ feet, and with a space of 27 inches height above the grate-bars. The ore came usually from the lead deposits of the neighborhood, "a lot" may be considered a representative sample, showing the following composition:

	Per cent.		Per cent.
ZnO,	53 997	SbO_3,	0.170
Fe_2O_3,	4.263	PbO,	trace.
Al_2O_3,	0.632	CO_2,	24.302
FeO,	1.039	SiO_2,	8.510
CaO,	2.393	S,	0.242
MgO,	0 546	H_2O,	2.414
CuO,	0 052		98.733
CdO,	0.173		

The bed coal was about 35 per cent. of the weight of the charge. The time of working was about four hours. The residue contained 25.426 per cent. zinc oxide; 12.528 ferrous oxide; 31.74 silica; 10.04 unconsumed carbon, besides alumina, lime, magnesia, sulphur, and copper. The following are the percentages of the foreign matters in the four grades of oxide produced at this establishment:

	"Star I."	"Star II."	"Star III."	"Oxide."
Zinc sulphate,	1.153	0.203	1.001	0.824
Lime "	0.008	0.041	0 080	0.011
Lead "	4.790	3.243	1.271	0 249
Lead oxide,	1.047	4 598	3.399	0.814
Copper oxide,	0.063	0 186	0.043	0.021
Ferric oxide,	trace.	trace.	trace.	trace.

NEW YORK MEETING.

FEBRUARY, 1877.

NOTE UPON THE COST OF BESSEMER STEEL RAILS.

BY P. BARNES, NEW YORK CITY.

SEVERAL interesting and important considerations may be based upon an analysis of the cost of producing Bessemer rails, and the facts thus set forth may be much more clearly emphasized by reducing each item of cost to its own fractional proportion of the sum total in each branch of the manufacture.

The estimate given below is not absolutely complete in minuteness of detail, but it may be fairly taken as a basis for the suggestions to be noted:

COST OF BESSEMER STEEL RAILS.

Item.	CLASS.	A. Converting.		B. Blooming.		C. Rail-rolling.		Item.
1	Stock...	Pig.	.629	Ingot.	.906	Bloom	827	1
2	Loss		.094		.036		033	2
3	Spiegel		.092		...		...	3
4	Fuel		.037		.012		.011	4
5	Refractories		018		...		...	5
6	Ingot moulds		017		...		...	6
7	Repairs		.027		013		009	7
8	General expenses		.015		.007		.017	8
9	Royalty		018		...		...	9
10	Labor		053		.026		.065	10
11	Crop ends		...		...		.038	11
			1000		1000		1000	

Perhaps the most striking comments that can be made upon this statement are those arising from a consideration of some of the smaller items, and even the least of these quite loses its insignificance when its proportion of the whole is expressed in actual money, as for the work of a year, or even for a single day.

Thus, if the item A 5 be considered, the importance can be clearly

shown of the facts and suggestions noted in Prof. Egleston's paper on "Refractory Materials," as recently presented to the Institute. Assuming a product of ingots of 250 tons in each twenty-four hours, and that their money cost may be put at $39 per ton, then the money total of A 5 becomes $176 per day. If, by a little closer watching or stinting, a saving of one-tenth of this amount can be made, there will be realized, on three hundred days' working, the handsome sum of $5300.

If, again, item A 10 be considered, and it be assumed that, with returning prosperous times, an advance of 5 per cent. were to be conceded, then this, on the preceding supposition as to quantity, would amount to not less than $7750 per year of three hundred days.

If item B 4 be noted, it will be found that if coal could be burned 5 per cent. more closely out of the ashes and clinkers, there would be realized a saving of $1755 per year.

If item C 2 be noted, it may be determined that, if by more careful heating the furnace waste can be reduced by one-tenth of its actual amount, the net saving on a daily product of 200 tons will be for the year not less than $9700, if the money cost of the rail be taken at $49 per ton.

One other general observation may be made in reference to item C 8. If such a thing could be imagined as that additional skilled supervision were to be employed, say to the amount of $5000 per annum, then it may be determined that this addition to general expenses would increase it by not more than 10 per cent. of its present proportion of the cost, the fraction due to C 8 being thus made .0187 instead of .0170. In other words, the addition of $5000 of salary per annum in such an estimate would increase the total cost of production by less than two-tenths of one per cent. of its present amount.

If, again, in consequence of this proposed addition to the skilled supervision of the establishment, the saving already noted of 10 per cent. in item C 2 could be effected, and there could also be saved by this same means say 5 per cent. in item C 4, and 5 per cent. in item C 7, and 10 per cent. in item C 10 (and these are by no means unreasonable suppositions), it would be found that a net saving would accrue of a sum not less than $32,000 per year of three hundred days.

These, in some respects, are striking figures, although they are no more than many of our manufacturers and engineers are making for themselves day by day, especially when rearrangements or improvements in the details of manufacture are to be considered. Such

comparisons are clearly to be commended for frequent use by those who desire to learn the precise results attained in daily practice, and to see in the clearest light the possibilities of improvement.

MR. METCALF said, in reference to the item of reheating, that where Siemens furnaces are used a saving of about 10 per cent. to 15 per cent. of fuel can be made by using a solid cast-iron bottom—an immovable bottom—made up of Tupper bars, or any other equally good bars. The saving is threefold—first, There is no dropping out of large quantities of good incandescent coke when drawing the lower bars in cleaning; the lower step grate is removed and the clinkers are drawn out with a hook when necessary. Second, When the gas-maker pokes his fire and shakes it down, there is no such thing as the poker going clear through to the ash-pit, spreading the bars, letting out the fuel, and making a passage into the gas space. Third, The coal is consumed more thoroughly and evenly, and the fire is in every way more manageable, with a good bed to work on.

NOTE UPON METHODS OF DRAWING METRIC AND OTHER SCALES UPON ENGINEERING PLANS.

BY P. BARNES, NEW YORK CITY.

IF it be admitted that the use of the metric system of measurement is desirable, and that it will be well, as urged by one of our engineering societies, to show upon all our plans or drawings a metric scale in addition to a scale of inches, then it becomes important to introduce some ready means of drawing these scales.

For many present purposes it is quite sufficient to space off and to draw them with the common dividers and the right-line pen, but if the number of drawings made or copied in an engineer's office, and upon which scales must be shown, is more than two or three daily, then some more mechanical or automatic means should be provided.

For a great majority of detail drawings, a simple transcript of the surface of a good two-foot rule would answer every purpose, and probably the best comparative showing of the metric scale would be made by drawing a line of millimeters close by the side of the line of sixteenths. This would be in fact little more than the

transfer of one of the common copper-plate comparing scales to the surface of the drawing itself. For most detail drawings this comparing scale ought to be at least 18 inches long, so that any dimension less than 18 inches can be taken off at a glance, and hence some mechanical appliance becomes indispensable for the prompt and accurate drawing of the scales.

The old-fashioned stencil-plate is obviously the first thing to be thought of for this purpose, and for a great deal of such work it is of course perfectly adapted. If, however, it is needful to make fine hair-lines, and to make them only sixteenths or millimeters apart, then one difficulty at least will arise, that of keeping the stencil constantly in perfect order so that the lines shall be certainly and accurately made.

The next thing likely to be thought of is some form of printing press or stamp, and this could be made to answer perfectly if the total length to be printed was only 3 to 4 inches; but for the assumed length of 18 inches, the press and stamp that would be needed might be costly and troublesome to handle. An obvious modification of this is a rolling stamp by which the lines of the scales may be printed, but the task of inking a roller properly, if used for printing in the ordinary direct way, might prove troublesome and difficult. If, however, a roller or rolling disk be used in connection with and upon a strip of carbon paper, then the trouble about inking and keeping the roller in good order quite disappears, though the question may remain whether the common carbon paper will answer perfectly for printing upon all kinds of drawing paper and upon tracing cloth.

It might be found that a steel disk could be made with the lines representing the fractional divisions so sharply raised upon its circumference that by rolling it across the drawing—guided by a T square or roller—the scale divisions could be cut clear into the paper, or depressed, so as to serve perfectly the needed purpose as if printed in ink or by a stencil.

It seems probable, however, that in order to print the sixteenth scale and the millimeter scale with one and the same movement of such an instrument across the paper, they would have to be cut upon separate rollers or disks, the circumference of each being so fixed as to give an exact number of inches and of centimeters in a single revolution. By this means all the larger fractional divisions can be given, each with its distinguishing length of line, and probably no very serious trouble could arise from the chance of one wheel being

stopped for an instant, while the other still revolved, in passing across the paper. A weight could be readily attached to such an instrument so that the two disks would bear uniformly upon the paper, and thus insure a perfect imprinting of the scales.

If the disks were made as large as 6 inches in diameter, thus giving the desired 18-inch length of scale with one revolution, then all the essential figures could be put on their circumferences so as to be printed at the same time with the scale lines. To engrave these figures, however, might add materially to the cost of the instrument, and in any case not much time would have to be spent in writing the needed figures with a pen.

It may be said that there is little new or strikingly useful in the device and methods thus suggested, but it sometimes happens that the definite and exact statement of what may thus be done in well-known ways has opened a way of doing the same things in better ways, and of doing some similar but more useful things besides.

NOTE.—Since the preceding was written, Messrs. Heller & Brightly have suggested that the disk or roller stamps would be costly and would require some special adjustments to insure their correct working. They are inclined to think, however, that a series of lines may be so engraved in relief upon a strip of metal that may be used for printing the proposed scales with perfectly satisfactory results with carbon paper or even with common printing ink. It would be needful only to lay the metal printing strip on the carbon paper and to rub it with the hand, or to press it with a simple heavy roller.

AMERICAN STUDENTS OF MINING IN GERMANY.

BY J. C. BARTLETT, A.M., CAMBRIDGE, MASS.

As American students of mining, philosophy, philology, music, history, or art have found it necessary or highly advantageous to supplement their course of study at home by a residence of some years at a foreign university, so, ever since mining has been practiced in this country in any other than a rude and wasteful manner, many American students of mining have sought in London or Paris, but chiefly in the Academy of Freiberg, Clausthal, or Berlin, such infor-

mation and experience as would give them confidence in themselves, and make them worthy of the confidence of those wishing the services of mining engineers.

But a broad distinction must be observed. Medicine, philosophy, philology, history, and art are universal sciences; their theories and applications are much the same throughout the civilized world; moreover, the principles of justice which underlie law, and the principles of mathematics, mechanics, chemistry, and geology, upon which the sciences of civil, mechanical, and mining engineering are founded, are also universal, but their practical application depends upon local conditions. The economy of mining is a function of such variables as government, labor, wages, distance, quantity and kind of ore, timber, water, and transportation, and to many it seems as absurd to attempt to obtain in any other country the knowledge to fit one to practice mining in America, as it would be to attempt, by studying law in a German university, to fit one's self for practice in the New York courts.

A young man who has decided to fit himself as a mining engineer is at a loss how to begin. On the one hand, he is told that our schools are not practical enough, that practical miners do not find the graduates capable of doing what they profess, and that he should study abroad, where theory and practice are united. On the other hand, he is informed that American methods differ from the foreign so fundamentally that, if he studies abroad, he must afterwards unlearn everything, and to learn mining he is advised to "go West," which now celebrated advice is somewhat indefinite. Truer but hardly less sweeping and discouraging is the opinion of the Commissioner of Mining Statistics, who said of the graduates of foreign schools, "Every such graduate has to reconstruct, alone and for himself, the whole art which he has learned—a work requiring genius as well as intelligent perseverance." It is, nevertheless, a fact that a large part of the prominent mining and metallurgical engineers and professors of our country have been students abroad, mostly in Germany, and it is fair to assume that their training was an important element or cause of their success; and since the annual exodus still continues, the belief is evidently widespread that our schools do not yet furnish all that is necessary, nor even the most important part.

In view of the immense mineral wealth of the country, in view of the present enormous production and the more enormous waste, in view of the fact that mining industries will always remain among

the most important sources of our national wealth and prosperity, the subject of the education of miners and mining engineers demands of this society earnest thought, thorough discussion, and, what is not to be forgotten, subsequent action. Moreover, the subject should be considered by itself, and not in connection with mechanical and civil engineering. In discussing education in general, we may come to general conclusions; in discussing technical education, to more definite conclusions, and in discussing mining technical education, we may reach still more definite and directly applicable results.

In the discussions of last February and June the two questions presented were not answered decisively, and perhaps they were questions not admitting unqualified answers; but much valuable light was thrown upon the whole subject, and an agreement was reached on some other important points, which, it will be noticed, were points of general technical education.

If civil, mechanical, and mining engineering are distinct enough to form three independent professions, the proper preparatory courses for each have points of distinction enough to warrant an independent discussion. We have had the general discussion—what we need is the special.

How, then, do our schools correspond to our mineral resources and existing appliances? Are American methods of mining and metallurgy, or foreign methods, or any definite methods taught in them? Are the attractive courses of the various catalogues and prospectuses given to students in reality? Are the requirements for the degree of mining engineer sufficiently exacting in theories and practice? These questions are asked in no spirit of criticism, but for information, with the hope of obtaining it for the benefit of present and future students, on the one hand from engineers of the Institute who are in practical life, and on the other hand from the professors in our schools. These questions are suggested to promote discussion, that the students may learn what is desired and will be expected of them as young engineers; that they may be told where and from whom they may learn what they lack; that the faculties of our schools may know what changes to introduce to make the courses more efficent, and that out of this discussion may be devised some means of establishing some connection between the schools and the mines and metallurgical works, so that our students may enjoy some such advantages as they are favored with abroad.

It may be well to consider some of the advantages and disadvantages of the German instruction, and to give some of the actual

experiences of the American student in Germany. For this purpose, the academy at Freiberg will be considered, because it is there that the greater number of our past students have studied; the greater number of those now abroad are there, and it is the school with which the writer is best acquainted.

Admission to the academy is very easily obtained. If the applicant from a foreign country can understand what the director says to him when he makes personal application, and can speak a very moderate amount of German, and can produce a diploma awarded to him by any college or technical school, that is sufficient. Not having a diploma, he may, instead, pass an easy examination, much similar to that required by our own technical schools for admission. In the statutes we read, "In suitable cases, especially in the case of applicants from foreign countries, the director may dispense with the admission examination." We also read, "Older and independent persons, and such as have already completed higher technical studies elsewhere, may be permitted by the director to attend lectures and practical exercises, upon the payment of the regular fees," etc. Such students are called Hospitanten, and correspond to our special students. Under these liberal regulations, there is no difficulty in entering. I have heard of one American, some years ago, who could not gain admission, but he was so totally deficient that he has not learned anything to this day. It seems to be the desire to make the entrance easy, not for the sake of securing students, but to avoid throwing hindrances in the way of those wishing to learn; and, in general, the kindness of the director and of the professors to all foreign students is very marked and gratefully acknowledged. This leniency, often a desirable accommodation for the mature student, is often a serious disadvantage to the young student not familiar with the German language. Not being able to understand much of the lectures, and his previous education not having been such as to enable him to pursue intelligently the mathematical studies of the course, he quickly becomes discouraged and lazy, and too often yields to the manifold temptations of Freiberg life. At all events, the foundation being poorly laid, the superstructure is insecure. Too easy entrance examinations are not a peculiarity of foreign schools.

The theoretical instruction is mainly imparted by lectures, a system which is perhaps the best for highest instruction of the universities, but which in a technical school, where hardly more than the elements can be given, is very wasteful of time and unsatisfactory. If

a professor has something original or new to offer, or if his subject is one on which good books are rare or expensive, then lectures are justifiable and necessary; but to give entirely by lectures a course on ordinary mathematics, mechanics, surveying, mining, theoretical chemistry, or any subject on which there are scores of good and inexpensive books, is a wicked waste of the time of professor and students. To illustrate, let us suppose the subject is mining, and the particular subject for the day is power drills. The lecturer gives, perhaps, a short history of the invention of the steam or compressed-air drill, and then proceeds to discuss the various systems; he makes an elaborate freehand drawing of a steam drill, and lectures while he draws. Now the student may take his choice; either he may copy the drawing as well as he may, being, perhaps, a poor draughtsman, or he may write the description and criticism; but, recognizing the uselessness of having one without the other, he generally tries to get both, and if he writes an intelligible description he may have time to copy half the drawing itself before the figure is rubbed out to make room for something else. Or perhaps the student devotes his main energy to the drawing and keeps pace with the professor, when suddenly the latter discovers that he is making his drawing out of proportion, and with a stroke he erases a third of his work. The student, who is working with ink or pencil, cannot introduce changes so easily and neatly. He scratches or rubs out or begins again, and perhaps gets a passable drawing and a fair description. Meanwhile the professor has drawn and described another drill, and closes his lecture with the remark: this last drill is in general use; the one before it has long since gone entirely out of use. Let us suppose the student hears lectures on some mathematical study. At his room he conscientiously rewrites and studies his notes, and finds that he has omitted important steps in the reasoning; he misses a lecture perhaps, and not being able to make good the deficiency without copying the probably imperfect notes of some friend, he loses his enthusiasm, goes to lectures less frequently, or finally not at all. These are not fanciful examples, but such as are occurring constantly. It requires much more determination and perseverance than can reasonably be expected of a young student, though he starts with resolution and enthusiasm, to write, rewrite, and annotate a whole treatise on each of the studies he pursues. And when he has it all done, he may find nine-tenths of it more fully given and better expressed in any of the excellent textbooks. Add to these objections, which apply in the case of all students, the fact that the art of writing German rapidly, of paraphras-

ing a lecture, is not easy for a foreigner to acquire, and we may imagine how little good our students would acquire if the main benefit of a residence at Freiberg were to be gained from the lectures.

Connected with some of the courses of lectures there are weekly recitations which are very thinly attended, sometimes as few as two or three or even none out of a lecture division of thirty or forty being present. This non-attendance proceeds from various causes; some students may have been irregular at lectures, many do not take the trouble to read their notes, at least for months or till just before the final examinations; some are not willing to make an exhibition of bad German, and some have not been able to get enough out of the lectures to be questioned on.

As regards discipline, the school is conducted on the most liberal principles, the student being allowed to select such lectures and practical exercises as he wishes, and to attend or not as he may choose. The only exception to voluntary attendance which appears in the statutes is contained in the following extract, "Students who receive scholarships, or from whom the fees have been entirely or in part remitted, are required (*verpflichtet*) to attend the recitations," which significant clause implies that recitations are important, and so important that mild coercion is justifiable. As foreign students receive no pecuniary assistance, but are charged $25 a year more than other students, this restriction does not apply to them. Moreover, students are not required to give any proof of progress unless they are candidates for a degree, and then only at the end of their course. In consequence of this freedom, many who are registered as students scarcely ever attend any lectures or other exercises. Sometimes an example is made and a young man is sent away, ostensibly for neglect, but in such cases it will be found that he was otherwise a bad character, and had made himself notorious in the town. This *laissez faire* principle may be allowable for the oldest and best students, but for the greater number, especially for those away from the supervision of home and the more exacting social restraints of our country, it is certainly pernicious. It is seeking for itself a foothold here, but it is to be hoped we shall stand by our practice of requiring proof of progress, regularly and frequently. It is said that a student who is required to prepare a certain number of pages for a recitation, or a certain subject for an examination, does not have the proper object of study placed before him; that he ought to be encouraged to study for the love of knowledge. This is perhaps the kind of suasion to apply to those who are destined to become ardent lovers and devotees

of abstract science; but becoming a successful engineer is probably as lofty an object as the ordinary student of mining will appreciate, and the advisability of showing him from time to time just how far advanced he ought to be, and whether he is actually up to the mark, is a sufficient reason for recitations and examinations. Habits of industry, as well as facts and theories of science, are to be inculcated and maintained. The German school acts on the assumption that such habits have already been inculcated in the preparatory school—an assumption not justified by experience. We cannot afford to allow a promising but lazy fellow to go to ruin through neglect, and we ought, for the interest of all concerned, to weed out, long before the end of the course, such as nature plainly intended to shine in some other sphere of usefulness. It is also said that our young men are too old and manly to be treated longer as schoolboys, and, now that it has been suggested to them, the young men themselves feel that their dignity as gentlemen is wounded. But at West Point or at the Naval School, where honor is generally assiduously cultivated and carefully guarded, the young men still contiuue to bear up under the degradation of being obliged to turn out early and make their own beds, or stand up stiff and straight before a blackboard and demonstrate a proposition in military style. A certain amount of discipline is necessary for efficiency in any body of men, be they men or really boys, and especially is strict discipline necessary for those who expect afterwards to exercise authority.

In what, then, does the superiority of the German mining schools consist? Why do our young men pass by our magnificently endowed and appointed schools without entering, or pass from them to spend two or three years at considerable expense and discomfort at Freiberg? It is mainly because the Freiberg Academy gives its students the union of science and art; because it furnishes them with ample facilities for learning, either within its walls or in the neighboring works, or somewhere in Saxony, or somewhere in Germany, the *practice* of the various processes of mining, concentration, and smelting. Moreover, it is distinctly a school for mining and metallurgy, untrammelled by any connection with mechanical or civil engineering; its professors are specialists, generally of the highest ability; there are no fancy courses in its instruction, and no more than two or three courses which might perhaps be considered superfluous. The following is a list of the professors, the subjects of instruction, the number of hours of lecture given weekly in each subject, and the practical exercises:

GRETSCHEL.—Higher Mathematics (Trigonometry, Analytic Geometry, and Calculus), 6; Selections from the Higher Mathematics, 2; Descriptive Geometry, 4; Introduction to the Theory of Determinants, 1; Graphic Calculation, 1.

UNDEUTSCH.—Mechanics, 6; Mining Machinery, 4; Machine Drawing, part first, 4; Machine Drawing, part second, 4.

VIERTEL —Geodesy and Mine Surveying, 3; Practical Exercises in the field (Summer term), ½ day; Practice in Surveying, including Mine Surveying, ½ day.

WINKLER —Inorganic Chemistry, 4; Organic Chemistry (Summer term), 2; Chemical Technology, 2; Quantitative Analysis, 1; Practice in Qualitative and Quantitative Analysis, from 9 to 6 daily except Saturday; Volumetric Analysis, 1.

RICHTER.—General Metallurgy, 4; Assaying, 1; Practice in Assaying, ½ day; Blowpipe Analysis, 2; Practice in Blowpipe Analysis, 2.

LEDEBUR —Metallurgy of Iron, 4; Metallurgical Technology, 4; Salt Works (Summer term), 1; Assaying of Iron (Winter term), 1; Practice in Iron Assaying (Summer term), ½ day.

WEISBACH.—Mineralogy, with one hour recitation, 5; Practice in Determining Minerals, 4; Mathematical Crystallography (Winter term), 1; Practice in Determining Crystals (Summer term), 1; Pseudo-morphology (Summer term), 1.

STELZNER —Geology, with one hour recitation, 5; Ore Deposits, 2; Petrifaction, 2; Microscopic Examination of Minerals and Stones, 1; Practice in the same, 1; Practice in Determining Rocks (Summer term), 1.

ERHARD.—Experimental Physics, 5; Practice in Physical Manipulations, 2; Fuels and Furnaces, 2; Meteorology (Winter term), 2; Mathematical Examination of the Physical Properties of Gases, 2.

KREISCHER —Mining, part first, with one hour recitation, 5; Mining, part second, with one hour recitation, 5.

MULLER —Construction of Buildings (Winter term), 3; Estimates for Mining and Smelting Buildings (Summer term), 3; Designing and Drawing of Mining and Smelting Buildings, 4.

FREIESLEBEN.—General Law (Winter term), 4; Mining Law (Summer term), 4.

SCHOBER.—Political Economy, 2.

WALTHER.—Hygiene of Miners and Smelters, 2.

OSTUCKENBERG.—Freehand Drawing, 4.

Great satisfaction is universally expressed with the lectures and practical exercises under Richter, Gretschel, Winkler, Weisbach, Stelzner, Viertel, and Ledebur. These departments are the strong attractions of the school, and better instruction than is given in the practice of wet and dry assaying, blowpipe analysis, chemical analysis, mineralogy, geology, surveying, and survey plotting, could not be asked. Moreover, the large and valuable collections of minerals, geological specimens, and models of machinery are accessible for inspection or study. With the professor of mining, or machinery, or geology, or iron, the students occasionally, perhaps

two or three times in a year with each, have the opportunity of visiting works or making geological tours in and out of Saxony.

These trips are sometimes of profit professionally, but a crowd of twenty students spending several hours only in large and complicated works, passing rapidly from one thing to another, cannot be expected to carry away much definite information or many lasting impressions. The geological trips are perhaps the most useful and enjoyable; the study of the Quadersandstein of Saxon Switzerland is not so engrossing that the beauties of this charming region pass unadmired; the wonderful formation of the Prebisthor does not preclude an appreciation of its beer, and the tramp over its wooded hills or through its cultivated valleys is enlivened by those glorious German student songs.

But thus far our schools offer as much, and there is no reason why they may not actually give as much, as the Freiberg Academy. We have larger, more convenient, and better appointed buildings; we have more money; we have equal facilities for laboratory and field practice, except in mine surveying; we have visits to works, geological trips, and summer excursions. Nay even, our schools ought, for the American student, to be very superior to any German school. American methods and machinery are hardly mentioned at Freiberg, and certainly do not receive the attention and discussion which their importance and the presence of a large number of American students might justify. American pumps, drills, engines, waterwheels, amalgamating machinery, and metallurgical processes are quite ignored, and American hydraulic mining is disposed of in about five minutes with some apparently fabulous accounts of hundreds of miles of ditches and the washing away of whole hills. In fact, the student gets nothing peculiarly American from his course, and hence what he learns outside of general principles he must unlearn, or at least reconstruct. But the one great advantage overtopping all others and outweighing all deficiencies is the intimate connection of the academy with the works of the vicinity, and the permission to visit and study similar works, which is granted throughout Germany, and also in Austria, to the holder of the Freiberg student's card. Almost no limits or restrictions are placed upon the student; he may, on proper application, either before his theoretical course or during it, make what is called a practical course. In this case he is placed under the direction of a mining captain, who puts him through all the different operations of mining, giving him information on each operation, answering cheerfully all questions, and assigning him a

place to work in this or that gang of miners, who are also invariably very kind and willing to assist by information or example. Or he may make an independent course, and visit any of the mines in the vicinity every day, or as often as he likes. In the same way he has perfect liberty to visit and work in the ore-dressing establishments about Freiberg, or in the excellently managed coal mine and washer at Zaukeroda, near Dresden. He may study in a similar manner at the Muldner and Halsbrückner smelting works, and as a good foundation for such study a practical smelting course is given during the first two weeks in August at the works by the professor of metallurgy or his assistant, which any student upon application may attend. Nor are less advantageous facilities granted outside of Saxony. It was the privilege of the writer, with one or two companions, to spend some two or three weeks in the summer of 1875 in the ore-dressing works of the Harz, at Clausthal and the neighboring towns, Grund, Lautenthal, and St. Andreasberg, and in the summer of 1876 some two weeks in the mines and ore-dressing works at Pzibram, in Bohemia; again two weeks in the Harz, and about the same length of time in works near the Rhine, at Laurenburg, Ems, Mechernich, and Cologne. At no place was permission to examine the works refused. On the contrary, the directors and overseers were everywhere willing to impart any information in regard to their works, and spent much time and pains in so doing. Permission was given to make sketches, take notes and dimensions, copy working drawings of machines, and statistics as regards cost of working and working capacity. The Germans and Austrians are particularly kind to foreigners, and they ask and expect nothing in return except the appreciation on the part of the student. Other young men, who were studying coal or iron in other places, were equally well received; the testimony from all sources is the same. Herein lies the great advantage of studying in Germany, and in spite of discomforts and expense, and objections such as have been mentioned, our students will continue to go thither till some definite, sure, and permanent connection is established between our schools and the mines and metallurgical works.

Last year there were at the Freiberg Academy 139 students, as follows: from Germany 64, including 42 Saxons; from Wallachia, Spain, Portugal, Holland, Asiatic Turkey, 1 each; from Switzerland and Japan, 2 each; from Italy and Norway, 3 each; from Greece, 5; from England, 9; from Russia and Poland together, 11; from Austria-Hungary, 11; from America, 24. Of the 24 from America,

1 was from Canada, 2 were from Chili, 3 from Mexico, and 18 from the United States. Of these 18, 1 came from each of the States of Alabama, Connecticut, Iowa, Louisiana, Maryland, Massachusetts, Michigan, and Ohio; 2 came from California, 3 from Pennsylvania, and 5 from New York. Of the 18, one was pursuing especially the study of mineralogy, one the study of iron, two of coal, four general metallurgy, and ten mining and concentration, or were not pronounced. Of the 18 perhaps a half were hard workers, a part of the remainder worked easily, the rest made no pretensions, but were going to begin. In general, the reputation of the students from the United States is good among the professors, at the works, and in the town. Together with the English and Canadian students, with whom they stand on terms of intimacy and friendship, they form the largest distinct foreign element, being about one-fifth of the whole number—a very creditable element, exhibiting the robustness and energy which characterize the English-speaking people everywhere. Thither, also, they carry their fondness for, and proficiency in, outdoor athletic sports, which are not cultivated by the other students. In skating they have no rivals or competitors, and in other games, such as base-ball and foot-ball, they have the field alone. Although this muscular development is not mental training, it is nevertheless conducive to mental activity, and the vigor and originality of the English race are largely due, perhaps, to physical health and freshness caused by the active outdoor sports practiced from boyhood up to and into manhood.

The principal subjective drawbacks to the progress of the American student in Germany are youth, an insufficient previous training in habits of study, and want of a working knowledge of the language. The first two generally go together, and often all three are combined; in which case the young man easily falls into ways of idleness and dissipation, which make his stay in Germany worse than useless, if they do not prove his utter ruin. To obviate these objections, it may be allowable to suggest as a course of study a collegiate course followed by two years in a mining school at home, and then one or two years abroad; or, what would be a saving of time and obviate the course abroad, a college course followed by two years in one of our mining schools, the time from the first of May or June till October in each of these years being spent at mines or works. It is now generally acknowledged that a liberal education is the best foundation for a professional training, and certainly, if the profession of mining engineering is to rank with the other liberal professions and be ac-

knowledged by them, such a foundation is necessary, even if it does require as much time as is required by the other professions. Under the first plan a young man would be ready to reconstruct his art at the age of 25 or 26, and in the second case to begin work at 23 or 24, or one year later if it should be considered expedient to require another year of steady work after the two summer courses already indicated.

The preparatory schools for our best colleges are the best training schools for boys, for the one reason, if no others, that they not only have a definite and not insignificant amount of instruction to impart, but that this instruction is to be tested by the broad and strict examination for admission to college, and it is a fact, unpalatable indeed, that those who, by reason of physical or mental weakness or indolence, are not capable of being brought up to this standard, deviate to a technical school, where they are nursed for a year or two till they are strong enough to leave and go into business.

While in college the student may, besides attending faithfully to his literary subjects, anticipate the mathematics, chemistry, physics, modern languages, a part of the geology and mechanics, and some other studies, so that in two years at most he may finish the course in one of our mining schools. Then, if he wishes to study in Germany, he has a character all formed, a liberal and technical drill, and a good knowledge of the language.

The devising of a plan for the union of the schools and works is full of difficulties. The conditions are so widely different here from what they are in Germany that the introduction of the German system without important modification is practically impossible. There both schools and mines are, to a great extent, directly under the control of the government. It grants to the student the right to assume the responsibility of an engineer only after he has served as "practicant," and requires the mines to receive its students in such capacity. As our schools and works are all private enterprises no other than a voluntary arrangement can be made here. There competition is not so sharp and speculation is not so wild as here; the richness of good mines does not have to be concealed to freeze out undesirable owners, poor mines do not have to be puffed to effect a sale, and patent machines and secret processes are not so common, consequently permission to visit works is more readily obtained. Moreover, our schools are more numerous, and are already established far distant from the important works, which are scattered far and wide, separated by many hundreds or by thousands of miles,

and often difficult of access. Very strong arguments were presented, as you remember, by the United States Commissioner of Mining Statistics, in 1868, and again in 1869, in favor of a national school of mines. As yet the government has not seen fit to act according to the suggestions, and I am not aware that the subject is likely to receive the attention of Congress. It would be impossible to locate such a school anywhere in this country as advantageously as the German institutions are situated, from which in a few hours, or in a day or two at most, any of the large mines or works may be reached. In consideration of this fact, and the possibility that, on account of State or local jealousy or interests, or political jobbing, or for other reasons, the foundation of a national school west or east of the Rocky Mountains may be delayed indefinitely, and of the fact that we already have millions of dollars invested in magnificently equipped mining schools, is it not advisable, instead of seeking other millions, to endeavor to increase the usefulness of those already invested? We certainly have schools enough, more perhaps than we have teaching ability to supply. One great and just criticism on American education is that we have so many institutions that the instruction is too dilute. Two or three good professors in a mining school cannot of themselves make that school satisfactory, and drawing away a good professor from this school and that to found another weakens those drawn upon, and generally adds another to the long list of moderately efficient attempts.

Cannot and will not this Institute, having as members representatives of the schools and practical engineers, become the instrumentality to bring about the desired union? Cannot the Institute, through its Council, or through a special committee appointed from among its members, draw up a circular (unless some better method of making a beginning is suggested) to be sent to the schools and to the principal mines and works, stating the advantages which other nations offer their students, the disadvantages under which our students now lie, the benefit which might result not only to the students but also to the mines—in short, a strong and complete statement of the case, and asking co-operation? The benefit which might reasonably be expected to accrue to the works should be particularly considered, because there is great misapprehension on this point.

The works generally consider that they only grant favors and receive no good in return, and perhaps from their previous experience they have reason to consider the students nuisances. But it is not so abroad, and there is no reason why it should be so here. The

labor of the student would not be worthless, and, indeed, to secure the owners against imposition or loss, and to insure diligence on the part of the student, the power of discharging an unfaithful young man would, of course, be one of the rights reserved by the works. Moreover, the works, always having several young men making a practical course, would have an excellent opportunity to select from the number some who would be valuable men to employ permanently, first as assistants and eventually as engineers. Moreover, as part of the compact, the schools might agree, as some return for the kindness of the owners, to furnish assays, or analyses, or geological opinions, or surveys, or plans, or drawings, or render some other assistance to the engineer of the works. It is by no means a case in which the favors are of necessity all on one side.

To begin on something definite, the circular might contain a preliminary plan of operations, and might ask each mine or industrial work and each school whether, on the proposed basis or on any basis, it would co-operate; it might invite criticism and suggestions for improvements on the plan, and from the discussions before the Institute, and from the answers to the circulars, a final arrangement might be made and put into operation.

The Chairman, Dr. Raymond, after praising the ability and discriminating judgment of the paper of Mr. Bartlett, said, with reference to that gentleman's citation of opinions from one of the early reports of the United States Commissioner of Mining Statistics, relative to the establishment of a National School of Mines, that his own views had undergone some modification since that expression of them, or, rather, circumstances had changed, partly through the rapid extension and improvement of local technical schools, and partly through the labors of the Institute of Mining Engineers, so that the crying need of a governmental institution to unite and elevate the profession no longer clearly appeared. This change of the situation, added to the sense which he had always entertained of the danger of failure in attempting to maintain a school of the kind under the supervision of a government republican in form, and peculiarily exposed to changeful partisan control, led him to say that he did not at present feel inclined to urge the establishment of a National School of Mines.

With reference to the advantages of study abroad, he thought Mr. Bartlett had, perhaps, not sufficiently emphasized two elements of profit which study at home could not replace, namely, the acquired

familiarity with one or more foreign languages, and with foreign technical practice. These are gained almost incidentally, like extra premiums thrown into the bargain. Their value throughout a professional career is scarcely to be estimated.

While it is quite true that the system of instruction by lectures alone is deficient in that patient training which American students, not college graduates, are likely to need, and which German students have usually received in the *gymnasium*, it must not be forgotten that the professors at foreign technical schools are extremely cordial to American students who show themselves to be in earnest, and that they devote much time, outside of lecture hours, to friendly assistance of deserving and appreciative pupils in special or regular courses. Dr. Raymond said that this sympathy and co-operation often extended through many years after the departure of the student from the school. He had no doubt that the experience of many graduates at Freiberg, now members of the Institute, would corroborate his own in this respect. He had received at intervals for sixteen years letters from his old instructors at that school, full of information, news, scientific and professional suggestions, etc., freely tendered and most valuable. No doubt a similarly pleasant and profitable relation existed between the professors and the graduates of most technical schools. Whenever this was not the case, it was usually the fault of the graduates, since nothing was in general more welcome to professors, more or less cut off by their duties from active career, than to maintain, through the young men whom they had trained, a vital connection with practice and progress.

With regard to the relations existing abroad between students and managers of works, Mr. Bartlett's statements were perfectly justified. As to the condition of affairs in this country, however, he must be allowed to say that he did not think secrecy a common evil here, and that our patent laws, however inconvenient they might be in some respects, carried this great benefit everywhere, that they abolished secrecy. The very word *patent* means something *open;* and experience showed that owners of patents desired nothing so much as to show them to everybody. In fact, as Mr. Bartlett would have occasion to find out, the difficulty was to avoid their importunities, not to break through their reserve.

Finally, he would suggest, that while it was perhaps outside the province of the Institute to attempt to establish an organic relation between students and the managers and owners of works, this object was in substance rapidly being accomplished by the very existence

of the Institute, and by the *entente cordiale* insensibly arising between these two classes, both of which are numerously represented among its members and associates. He had yet to hear of the first instance of discourtesy or lack of professional hospitality shown by one member or associate of the Institute to another, while he knew of many instances of the free interchange of professional information and service, reflecting great credit upon the parties, and illustrating one of the chief benefits of the organization.

PROF. FRAZER said that there were one or two points in Mr. Bartlett's paper which deserved especial notice. In the main he agreed with the views and statements he had presented. Mr. Bartlett was, however, mistaken in saying that foreigners never received pecuniary assistance at Freiberg. He knew of one American student who had received aid, and there had also been one or two Hollanders who had been assisted pecuniarily by the government.

In 1867 and 1868 there were about forty Americans in Freiberg, comprising about half the school. The American students had preserved an excellent record for conduct, and had more than half the best scholars. There had been some little dissipation among them, but not generally, as among the Germans. The class to which foreign student life was the most dangerous comprised young men of property, who came to Freiberg without any definite desire to study mining engineering or anything else, but to pursue the worst features of student life. One of the greatest advantages of the Freiberg school was the intimate connection of the mines and works and the government, whereby opportunity was afforded for practical instruction, under the most favorable conditions; and the presence of these mines and works in the immediate vicinity of the school obviated the loss of time which would otherwise be incurred. Prof. Frazer did not think favorably of the *quid pro quo* suggested by Mr. Bartlett, that the schools should do expert work for the works in return for favors shown to students. He thought it would be an injustice to professional experts, many of whom had no other means of earning their living than by doing just the kind of work which it was proposed here to supply gratuitously to the shops. The result of such a plan must be that the *quid* would come out of the living of these experts; for the institutions of learning, being self-supporting and able to do much work as practice which would otherwise have to be paid for by manufacturers, would gain in numbers by the increased facilities this arrangement would enable them to offer students. The students are the gainers by this or any system up to the time of their

graduation. After that time, unless specially provided for, such a rule would, more than anything else, keep them out of employment.

MR. J. FRAZER TORRANCE, of Montreal, said that it must be borne in mind, in considering the advantages which American students enjoy in visiting the mines and works in Germany, that the persons in charge of these works have themselves been in the schools, and are, therefore, able to understand the wants of the students, and to give them appreciative aid. He thought the last speaker had overrated the advantages of Freiberg as a place of dissipation, and considered it ill adapted to one who preferred spending money to study.

THE PROPERTIES OF IRON ALLOYED WITH OTHER METALS.

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THERE exists an unconfirmed opinion among many ironmasters that the combination of a small quantity of manganese, chromium, titanium, tungsten, aluminium, nickel, and some of the metalloids with iron has a beneficial effect upon the quality. And the impression prevails in some localities that the excellence of steel greatly depends upon the influence of some of these elements. But as the recorded experiments are so meagrely described, and made under such various conditions, the student in search of information upon the subject is somewhat bewildered by the contradiction of the opinions expressed. Observing some interesting phenomena while experimenting with an alloy of iron, copper, and nickel, I was led to determine the effect of some of the metals upon iron as free from contamination by other elements as it is possible to procure in practice, in order that the result of an alloy of an individual metal with iron might be more closely studied; for it is almost an impossibility to determine the influence of a small amount of one element upon a metal combined with a large amount of another, and the mere presence of another sometimes makes this difficult. And as most of the experiments recorded upon this subject have been made with iron containing sufficient carbon and other elements to interfere with the effect of that metal the influence of which it was desired to observe, I have endeavored to avoid these sources of error as far as practicable. In determining the specific gravity of the alloys in these ex-

periments, I considered it essential to saw out pieces from the ingots, so that the specific gravity of the samples might be obtained in the condition the molecules assumed while cooling down from fusion. This was done because no just comparisons can be deduced when the normal relations of the molecules have been disturbed. After many trials with iron alloyed with a single metal, and containing a minimum of carbon, I increased the amount of the latter element to the highest degree consistent with the alloy undergoing the same treatment as when the carbon was at minimum.

Iron and Nickel.—Liebig states that some of the alloys of nickel and iron which he examined had the appearance of genuine Damascus steel, receiving readily a beautiful damask, and according to M. Bergmann, nickel readily unites with iron in all proportions, producing a soft and tenacious alloy. I have been unable to produce an alloy of these two metals exhibiting evidence of damask by any of the treatments employed to produce it, even in iron containing as much as eight per cent. of nickel, but found, as M. Bergmann had, that a perfect combination resulted in every instance. In these experiments I employed a homogeneous iron, containing but a trace of sulphur and phosphorus, no manganese, nor other metal that could be determined by treatment with hydrosulphuric acid and sulphide of ammonium. It contained only 0.08 of 1 per cent. of carbon, and had a specific gravity of 7.766. I used in all the following experiments some 15 pounds of this iron, melting it in an uncovered crucible, placed upon the bank in the port-flame in a Siemens-Martin regenerative furnace. When the iron was fully melted, 0.8 of 1 per cent. of nickel was introduced, which caused a slight rising of the fluid metal, seeming to produce greater fluidity. After allowing the alloy to remain in the furnace some thirty minutes after the introduction of the nickel, it was poured into an iron mould, flowing freely and unaccompanied by the emission of sparks, as is characteristic of iron. When cold, the ingot was placed upon two supports across the anvil of the steam hammer, and subjected to several blows before it was broken. The appearance of the fracture was not distinguishable from that of the iron previous to melting. One piece of the ingot was turned, polished, and etched, but did not differ from the same iron unalloyed when subjected to the same treatment. Another piece was heated to a bright heat and placed under the hammer, when, after a few blows, it crumbled into fragments. Another was heated to a welding heat and hammered, forging well until the temperature fell to that of redness, when it broke into

pieces at every blow of the hammer. To sum up this experiment, then, the nickel exercised no appreciable influence upon the iron at a white heat, but at a red heat it rendered it highly red-short and worthless. Analysis gave nickel .732 per cent.; carbon, .07 per cent.; specific gravity, 7.787. Several other potfuls were melted, and the same per cent. of nickel added, under the same conditions, with like results. To determine the influence an amount of carbon approximating to the amount of nickel would have upon the alloy, the fragments left from the previous experiments were melted and the amount of carbon increased by the addition of a steel high in carbon and of excellent quality, together with a small amount of nickel to equalize its percentage with the carbon. As soon as this was thoroughly melted it was poured. The ingot was then forged, at a bright-red heat, into a bar $1\frac{1}{8}$ inch square, from which a piece some 4 inches long was taken, ground upon each side until good edges were obtained, when it was hardened by cooling at a red heat in a saturated solution of sodic chloride. It was again ground and applied to cutting a hard chilled roll. Considerable pressure was applied and a heavy chip taken, but at the fourth revolution of the roll the edge of the tool failed. The combination of carbon was here manifested by its main characteristic, hardness, evincing a tendency to moderate the effect of the nickel by allowing the alloy to be forged at a lower temperature than when containing a minimum of carbon. Another piece of this alloy was rolled, at a bright-red heat, into a shape $\frac{1}{2}$ of an inch by $\frac{5}{8}$, cut into pieces and chamfered for welding. The heated ends were dipped into fine sand to form a fusible silicate to obtain clean surfaces. They were then raised to a high welding heat and united. A firm weld was effected, but, upon hammering the piece until a low red heat was reached, the rod fractured upon both sides of the weld. The welded portion was then bent home, over the horn of an anvil, and cracked upon all edges, showing conclusively that the bar was red-short. We see in this experiment that the increase of carbon increased the hardness and counteracted, to a certain extent, the red-shortness which the nickel caused before, since the alloy in the second case forged at a lower temperature than in the first case, in which the alloy contained less carbon. And we also see that the nature of this alloy is red-short. Analysis showed:

Carbon,	.72	Specific gravity,	7.758
Nickel,	.66		

An ingot containing 6 per cent. of nickel and low in carbon was cast. When cold and fractured, it was not noticeably different from the fracture of the same iron unalloyed; its tenacity and ductility were but slightly impaired. But at a red heat it crumbled into fragments under the hammer. The specific gravity of this alloy was 7.851.

Iron and Copper.—Melting a quantity of the same iron used in the foregoing experiments, 2 per cent. of copper was added, when vapor of the copper arose from the open pot to a considerable extent. After stirring, the contents were poured as in the previous experiment. When cold, the ingot was fractured, exhibiting a dull gray fracture, of close, granular appearance. All attempts to forge it were fruitless, it being so red-short that it crumbled into grains. When turned, polished, and etched, it showed homogeneity, without distinct crystalline structure, but when heated and cooled in water, a film of copper appeared upon the surface of the piece. Broken when cold, it was decidedly weak, and when heated fractured readily. Although neither the alloy of nickel and iron nor copper and iron showed a fracture greatly different from the iron unalloyed, yet when the two alloys were melted together, forming an alloy of copper, nickel, and iron, the ingot fractured much more easily, and showed large, coarse crystals, radiating from the centre of the ingot, and a structure like that of spiegeleisen. It was decidedly cold-short, and although less red-short than either of the separate alloys, still it was not forgeable at any heat. When this was etched, a beautiful crystalline structure was distinctly visible.

Iron and Tin.—M. Karsten relates some experiments he made upon this subject in Siberia. He found that 1 per cent. of tin added to iron rendered it extremely brittle when cold, but not when hot, finding that the alloy could then be readily forged, giving out during the operation white vapors, which condensed upon the anvil and hammer. "M. Hervé found that an alloy formed of 100 parts of iron and 1 part of tin presented an even fracture, slightly granular, gray in color, dull, brittle, and hard." In alloying these two metals, I used the same homogeneous iron, containing .08 of 1 per cent. of carbon, particularly free from sulphur and phosphorus, and thoroughly melting it before adding the tin; pouring the alloy, after stirring, into moulds. When cold, the ingot was broken with comparative ease, showing a rather fine, bright crystalline fracture, somewhat honeycombed towards the centre, the holes showing the lustre of tin. Under the glass, the crystals were indistinct, and the

mass of spongiform structure. When turned, polished, and etched, it showed homogeneity. Under the shears it was dry, hard, and inclined to fracture rather than cut. It was decidedly cold-short. When heated to redness and passed through rolls, it broke into fragments. At a white heat, under the hammer, it flew into particles, some of which were sufficiently fine to ignite in their passage through the air. Although this alloy contained less than 1 per cent. of tin, it was rendered by it cold-short, red-short, and hot-short. Steel and tin alloyed showed the same characteristics. By analysis this alloy had tin, .73; carbon, .06; specific gravity, 7.805. Of all the metals I have alloyed with iron my experiments point to the fact that tin has the most hurtful effect. An almost insignificant quantity of tin in the absence of other metals renders iron cold-short. Having received for examination a piece of cold-short spring steel, of ordinary carbonization, which broke in punching, I discovered traces of copper and tin; and upon inquiry found that, at the manufactory, a quantity of brass and copper had been broken under a steam hammer at about the time of the manufacture of this lot of steel; and as the puddlers used the cinder from the hammer, it is probable fragments of the brass and copper found their way to the puddling furnace, and there entered into the product.

Iron and Platinum.—These metals readily combine at a lower temperature than is required to melt iron and in every proportion. Crookes and Roehrig, in their *Treatise on Metallurgy,* remark: "It is still problematical whether the small additions of platinum, silver, nickel, etc., exert that good influence attributed to them upon the sorts of steel known as platinum steel, silver steel, etc., or whether the good quality of the steel is due only to suitable treatment." The numerous experiments I have made go to show that the good quality of steel and iron, especially low iron, is due to the treatment they receive, and to their freedom from all foreign elements, with the single exception of carbon. My experiments have not shown another element that has the property of giving hardness to iron to the same degree without impairing its workable quality to a greater. Platinum alloyed with iron renders it hard, but less so than the same amount of carbon; while at the same time it prevents its being worked at as high a heat as the unalloyed iron, or the iron containing the same amount of carbon. The fracture of an alloy containing as high as 1 per cent. of platinum does not materially differ in appearance from that of the unalloyed iron. The grain, however, is somewhat finer, resembling the fracture of steel of about 0.3 per cent. carbon.

In rolling an ingot of iron alloyed with .82 per cent. of platinum and .08 per cent. carbon at a red heat, in a strand groove (it would work solidly in this if it would work at all), it broke into pieces two or three inches long throughout the entire delivery of the bar. At a white heat it would not bear the blow of a hammer without falling to pieces. Specific gravity, 7.861. The same iron, when containing 4 per cent. of platinum, and nearly 2 per cent. of carbon, at a low red heat was drawn under the hammer and rolled with but slight evidences of red-shortness, yet in quality it was not equal to the same iron having nearly the same amount of carbon without the platinum.

Iron and Aluminium.—Opinions as to the effect of aluminium alloyed with iron are greatly at variance. Most of the attempts to produce this alloy having been made with steel or cast iron, it is probable that the effect of the aluminium was neutralized to a certain extent by the amount of carbon present, and that the beneficial effect ascribed to the aluminium was really due to the carbon. An account in *Useful Metals and their Alloys* relates "that Faraday and Stoddard obtained an alloy of iron containing .064 of aluminium and some carbon by keeping under fusion during a considerable time a mixture of highly carburetted steel with alumina. The alloy was white, very brittle, and of granular texture." While M. Karsten attributed a mischievous influence to aluminium, Messrs. Faraday and Stoddard concluded that "aluminium in small quantities does not impair the quality of iron, and that it appears to considerably improve the quality of steel." "Gruner and Lan think aluminium to be more injurious than is generally believed, and for this reason presume the ores from Dannemora, which are poor in alumina, form an excellent material for the Bessemer process." In alloying aluminium with iron by using its oxides, I employed, by weight, twelve parts of emery, eighteen parts of alumina, one part of pulverized charcoal, and thirty-six parts of fine turnings of the same iron as used in all these experiments. After mixing the mass thoroughly, it was subjected to a white heat for forty-eight hours, and then placed in a port flame of a Siemens regenerative furnace, and allowed to remain uncovered as long as the crucible would stand the excessive heat. It was then taken out and the contents poured into a cylindrical iron mould. When cold, the ingot was broken, but with considerable difficulty. The fracture showed a solid homogeneous body of fine crystalline structure, resembling steel of about 1 per cent. of carbon. Heated to cherry-redness and placed under the hammer, it

forged remarkably well. But upon endeavoring to forge it at a yellow heat, it crumbled into fragments. A piece was rolled at a red heat and worked without cracking, and when cold this was broken, showing a very fine fracture, crystalline in appearance, inclining to silky-gray in color. Heating afterwards to a yellow heat a piece that had been rolled at a red heat, it failed under the hammer. It would not harden, nor was its resilience increased more than soft iron would have been by plunging it at a red heat into cold water. With an increase of carbon, I found that at the same temperature there was an increase of cohesion, while, with 1 per cent. of carbon, the alloy, with proper attention, could be worked without fracture, yet it could not be welded. It will be noticed by the analysis that the addition of carbon in the crucible increased the percentage of that element in the alloy. Analysis:

Carbon,	.20	Specific gravity,	7.727
Aluminium,	.52		

When the metal aluminium was added to a pot of melted iron, the product exhibited the same characteristics.

Iron and Antimony.—One per cent. of antimony was added to the melted iron without producing any unusual feature, and the whole allowed to remain twenty minutes in the furnace after the addition of that metal, when the alloy was poured into a mould, showing a slight rising in the centre of the ingot. The union of the two metals seemed to take place with freedom and much greater ease than lead, zinc, or copper with iron, these metals mostly vaporizing in a short space of time. After the ingot was cold it was struck with a small hammer to disengage some adhering scoria, when it fractured at the point of contact, exhibiting a honeycombed fracture of uneven, coarse crystallization, having the appearance of the fracture of blister steel of about $1\frac{1}{2}$ per cent. of carbon, such as the most highly heated bars of cementation exhibit. When heated and hammered, or rolled in a strand groove, it crumbled into pieces. By all tests applied it displayed decided cold-shortness as well as red-shortness.

Iron and Bismuth.—Having added .5 per cent. of bismuth to a pot of melted iron as heretofore, the contents poured freely without boiling or rising in the mould. When cold the ingot was broken with great difficulty, showing a beautiful fracture, resembling that of low Bessemer steel. The strength of the iron did not appear to be greatly diminished, although it was somewhat harder. M. Karsten endeavored to ascertain the influence of this metal upon iron; with this

object he tried several refining experiments (probably using cast iron), in which he added 1 per cent. bismuth. He found that the bismuth did not produce any unfavorable effect, except that of retarding refining, the bars appearing to have their usual strength. The iron of his experiments contained .08 per cent. of bismuth, and there is no record of how he conducted the process, nor what tests he applied to the alloy. As it is probable that the iron used contained a high per cent. of carbon, I am inclined to think that the influence of the bismuth was obscured by the excess of carbon, because, in all my experiments with this metal alloyed with iron low in carbon, decided red-shortness was observed when worked and rolled at a red heat. Analysis gave bismuth only a trace, carbon .08 of 1 per cent.

Iron and Molybdenum.—Molybdenum readily unites with iron, rendering the melted metal very fluid, settling well in the mould, and producing an alloy which cannot be worked on account of its extreme red-shortness. One per cent of molybdenum renders good iron utterly worthless.

Iron and Zinc.—When zinc was added to the melted iron, excessive boiling resulted, accompanied by copious vapors of zinc. When all vapors had ceased, the contents in the crucible were poured, and the ingot rolled while yet hot. It rolled well until reduced to a thin flat, when evidences of red-shortness appeared. The product of this experiment rolled better than that of any of the others, but still was seriously impaired by the zinc, although only traces of that metal were found by analysis.

Iron and Lead.—Results the same as with zinc.

Iron and Silver.—In this experiment the silver showed but little affinity for the iron. Five-tenths of 1 per cent. of pure silver was added to a pot of iron after complete fusion, and the contents poured twenty minutes later, flowing freely, and settling well in the mould. When cold the ingot was examined, and globules of silver found in the adhering slag and in the top of the ingot, and also in the bottom of the crucible. The alloy fractured with difficulty, showing a firm, solid fracture of fine crystalline appearance. The alloy was harder than the iron unalloyed. When rolled and hammered at a red heat it showed red-shortness. Analysis gave only traces of silver.

Iron and Cobalt.—According to Berzelius, "the alloy of these two metals is hard and magnetic, but the precise influence which different proportions of cobalt exercise upon the ductility of iron is not known." M. Berthier says "that the alloys of these two metals

have the same properties as pure iron, and are whiter." Observing traces of cobalt in most of the manganiferous pig irons and spiegeleisens and the iron made from these, which was often red-short, a more thorough investigation was given to the influence of this metal upon iron than to some of the others, many of which are seldom met with in practice. Five-tenths per cent. of cobalt, in the form of pure protoxide, was intimately mixed with a sufficiency of pulverized charcoal for its reduction, and placed in the bottom of a crucible, with turnings of the iron placed above, and upon this fifteen pounds of iron cut in small pieces. The whole was allowed to remain in the furnace until complete fusion was effected, when it was poured as heretofore, forming a solid ingot, tough when broken, and of clear crystalline fracture. When rolled into a bar 2 inches by $\frac{5}{8}$, it evinced but slight evidence of red-shortness. Desiring to test it for its suitableness for horseshoe nails—for which purpose the original iron was used—it was reheated and further rolled into a plate, having the heads of the nails formed by the rolls. By this rolling it cracked very badly upon the edges, some of the openings running half way across the plate; however, the nails were punched from the plate and finished, and when the customary test was applied to them they showed decided weakness, averaging but 20 per cent. of the strength of the original iron. Analysis showed cobalt .33.

PUMPING ENGINES.

BY JOHN BIRKINBINE, PHILADELPHIA.

In all metallurgical processes and mining operations, water is an element which receives attention from the management; and provision is required either for a means of supply, or for the disposal of accumulation. In many works the quantity of water to be furnished is sufficiently large to place the item of water supply of equal importance to the reception of material or disposition of product; and the means to be employed receive, or should receive, the most careful investigation.

There are exceptional cases where mines or quarries possess a natural drainage, but a large majority of the useful ores and the fuels delved from the earth are obtained from workings in which water accumulates and must be removed. Often the quantity to be

disposed of is very great, and the distance to which it must be elevated amounts to hundreds of feet.

The magnitude of the work to be done, either in furnishing a supply for large metallurgical works or in draining extensive mines, demands the employment of powerful machinery, the economical operation of which is of great importance to the management, both as a pecuniary and practical consideration. It is therefore probable that a few notes of the general character of pumping engines may prove interesting to many of the members of the Institute. No attempt will be made in this paper to go into details of special machines, but the general features of the different classes will be briefly considered.

When a large amount of water is to be elevated to any considerable height, the prominent question to be considered is not, What will sufficiently powerful machinery cost? but it is, What will be the cost per annum, or per ton of product, to drain the mine, or supply the works? as the case may be.

To obtain this information it is necessary to be in possession of the following facts:

1. Fuel consumed to do a given amount of work.
2. Durability, and liability to derangement, breakage, or repairs.
3. Cost of attendants, lubricants, etc.
4. Interest on first cost of machinery.

The items rank in importance in the order named.

The term "duty," as applied to pumping engines, indicating how many million pounds of water can be raised one foot by the consumption of one hundred pounds of fuel, is the generally accepted standard of comparison, and it is the true index of the merits of a machine when it is the result of long-continued operation, considered in connection with the other items above specified. A saving of a small amount of fuel each day is augmented into a large sum in a year, and represents the interest on a considerable outlay in construction.

Owing to the fact that in America it is mostly coal mines which require powerful pumping machinery, the "duty" of the apparatus has not been so jealously considered; for waste or culm is principally used for fuel, and the labor troubles have encouraged operators to employ cheap engines to a considerable extent, rather than economical ones of more expensive construction. But at these mines each ton consumed costs something to remove and handle, and therefore represents value.

An engine which is required to raise three hundred thousand (300,000) cubic feet (or two and a quarter million gallons) per day to a height of two hundred feet, would perform a work each day equivalent to raising 3,750,000,000 pounds one foot high. If this engine was capable of working with sufficient economy to give an average duty of sixty million foot-pounds (a duty within safe bounds), the daily consumption of coal would be 6250 pounds, aggregating in one year 1018 tons; if, however, it gave no higher duty than the average of American pumping engines, say twenty-five million foot-pounds, the daily consumption of coal would reach 15,000 pounds, aggregating in a year 2444 tons, a difference in favor of the 60,000,000 engine of 1426 tons. If this fuel cost but one dollar per ton, the saving would pay for at least two laborers' time, or if capitalized at seven per cent., would permit of an expenditure of $20,367 more for a 60,000,000 engine than for a 25,000,000 engine.

In mines where ores of the useful metals are extracted, the saving would be much greater, and in proportion to the cost of the fuel. If coal cost $4 at such a mine, the saving above would be quadrupled, and amount each year to $5703, representing a capital invested of nearly $81,500—a sum amply sufficient to pay for a very elaborate pumping engine of more than double the power above cited.

For many years the "duty" of pumping engines has received prominence in European mining countries, and most of the reliable data which we now possess are the results of the operations of engines at foreign mines. The English operators deemed it so important that prizes were offered to engineers doing the most work with 100 pounds of coal. While this had the effect of showing what the engines would do, and improving the average duties, it also brought into existence the various plans of "doctoring" pumping engines to secure exceptional and excessive duties by the exercise of sharp practices, thereby detracting from the reliability of some of the reports.

In America the records of duties are principally from water-works engines, but, unfortunately, many of them are the results of but a few hours' running, under the most favorable circumstances and with numerous allowances for imaginary contingencies, and do not indicate the daily operation of the engines. The duty of an engine is not to be considered the result of such a test, but it should be calculated from the water raised and coal consumed in a year or a series of years.

The liability to disarrangement of parts, breakage, and consequent repairs exists, of course, in all the machines to a greater or less extent; the ratio being practically in proportion to the number of moving

parts, and not to the weights of the machines. Care in proportioning, and attention to details of construction, greatly reduce the possibilities of accident; but the more numerous the wearing parts, the greater are the probabilities of repairs, and, generally, the shorter the life of an engine.

A pumping engine may give a high "duty," and yet be so short-lived as not to be an economical machine, for the numerous stoppages and expenditures required for repairs, or the rapid deterioration of the engine, often amount to more than the saving in fuel.

The cost of attendance, while entering into the calculation of the economy of an engine, does not attain the importance often ascribed to it; for the maintenance of any larger piece of machinery demands (and should receive) careful and constant attention from competent parties, and cheap engineers are among the most expensive features which can be introduced into any establishment. There is no just reason why a pumping engine should not receive as jealous and watchful care from skilled attendants as a blowing engine or rolling-mill engine, and yet some pumping machines are claimed as superior to others because "any boy can run them."

The amount of lubricants required for an engine are given a place in the comparison of different apparatus, not so much for the sum expended upon them (although this, in many instances, is no small outlay), as for an index of the durability of a machine, for generally the engines requiring excessive lubrication wear rapidly, and consequently are "short-lived."

The interest upon the first cost of an engine, very properly, is considered in the estimate of its efficiency; but it is often accredited with more importance than is justly due it.

The consumption per day of 100 lbs. of coal, or a quart of good lubricants, or a half hour's work in the machine shop for repairs, will, under ordinary circumstances, represent a greater amount per annum than the interest on a thousand dollars; therefore, where all these items are increased in any engine, its economy becomes doubtful, and any saving in its first cost is quickly absorbed by such daily expenditures.

These remarks apply to pumping engines without unnecessary ornamentation, for this should be a matter of separate consideration. Any good machine is worthy of a good workmanlike finish, and the addition of gilding, nickel-plating, fancy turning, or fresco painting is not to be estimated in the record of comparative economy. There are pumping engines now in use in this country which have cost, to

put in place, over $300,000, yet I greatly doubt if there is in America a pumping engine worth, intrinsically, to-day $100,000.

A pumping engine is a compound machine, made up of a steam engine (or the essential parts of one) and a pump (or pumps) combined, connected, and arranged in a great variety of forms.

The proper proportion and arrangements of the parts of an ordinary steam-engine are now so well understood and generally agreed upon, that, as a motor for converting the steam generated in boilers into work, there seems to be but little room for further improvement, and the direction of invention is rather towards obtaining better results from boilers.

Among the acknowledged essential elements for obtaining economic operation in a steam-engine, are high piston speed and expansion; yet a large majority of pump manufacturers consider slow piston speed as necessary to secure a high duty in pumping engines.

In dealing with such a ponderous and unyielding substance as water, there are many difficulties to be overcome in making a pump to work at a high piston speed, and it may be considered impossible to be able to operate a pump with the same velocity as is practicable with an engine using the lighter and more elastic form of water (steam) only.

The attainment of moderately high speed in pumping engines is, however, easily accomplished. Well-proportioned pumping engines of large capacity, which are provided with ample water-ways, and properly constructed water-cushioned valves, have been (and are now) operated successfully against heavy pressures, at a speed of 250 feet per minute, without "thug," concussion, or injury to the permanency of the apparatus, and there is no doubt but that the speed can be still further increased.

Although the pump for raising water antedates the steam-engine by some thousands of years, and is a more simple machine, yet, in the proportioning and constructive arrangement of parts, there appears to be no acknowledged standard. The pumps are made to force or push the water, or simply to lift the water; there are double-acting piston pumps, plunger pumps, or bucket and plunger pumps. They are worked singly, or in pairs or more, so connected as to deliver the water at different intervals. If we add to these the rotary and centrifugal pumping machines, and the numerous arrangements introduced to lift water by the condensation and force by direct pressure of steam, we have a variety whose name is legion.

In the details of pumps of a similar class, there are as radical

differences. Valves are made hinged or "flap," "poppet," "single-beat," "double-beat," or "treble-beat" (I prefer the expressions single, double, or treble seat as more expressive). They are made of leather, rubber, wood, brass, composition, or iron. In proportions they are constructed large enough to answer for each operation of charging or emptying the pumps, or they are divided up into a number of small valves. In fact, there is in pumps no acknowledged and accepted general arrangement in which intelligent mechanics and builders approximate an agreement.

In combining the two essential parts of a pumping engine, the steam-engine and the pump, there is as much difference of opinion and controversy as to the mode of connecting and the arrangement of the parts. Some are operated direct, the piston of the steam-cylinder being connected directly with that of the pump; others have intervening gearing, beams, or bell-cranks. A visit to the pumping works supplying our large cities will demonstrate the variety of design and arrangement adopted by various engineers; nor is this variety confined to the different cities, for many of them have, as a means of supply, engines differing materially, and the city which uses engines of similar design and construction is the exception rather than the rule.

The city of Philadelphia employs sixteen pumping engines in connection with its water supply, which represent ten distinct varieties. Providence employs four pumping engines, all of radically different types. Buffalo, Cleveland, Cincinnati, and other large municipalities are similarly provided.

To secure the advantage of a high piston speed in the steam-engine, and operate the pump at a slower velocity, numerous designs have been introduced. One of the largest engines of late construction, built to secure this result, is a vertical compound steam-engine, transferring its power through gearing to horizontal pumps. The great objections to such a design are the multiplicity of parts, and the difficulty of procuring gearing which will operate without back-lash or play between the cogs.

Another engine, which is also of late construction, consists of a compound engine, each cylinder operating a pump by means of a rocking or oscillating beam, the connecting rods of the steam-cylinder and of the pump being so disposed that the steam-piston passes through double the stroke of the pump-piston, but the same number of strokes are made in a given time, and the difficulty generally experienced is in the change of direction of the water, and the open-

ing and closing of the valves, and not in the actual speed of the piston.

In an article published in one of our engineering journals the untenable position is taken that a multitude of small valves offers less resistance to the flow of water through them than one large valve, while practice demonstrates that large valves offer less resistance proportionately than a number of small ones aggregating an equal area; and if double-beat valves are employed of appropriate construction, they will close as soon as the current of water ceases to flow through them, without the addition of weights or springs or the return current of the water. In using a number of small valves it is found necessary to load them, or to hold them down by springs, particularly if they are of rubber, to insure their closing; and even then it is rarely found that they all close properly; an examination of a pump using such valves generally exhibits some of them chipped or held partly open, and a consequent loss resulting. A valve should be complete in itself, and the necessity of the employment of extraneous forces to produce the proper operation of the valves is evidence of a defect of construction or a want of adaptability for the purpose for which it is employed.

In a recent test of a pumping engine an allowance is made for a pressure of six pounds per square inch for the operation of each set of valves; this seems excessive, for it reduces the suction power of the engine so that it cannot draw the water over eighteen feet. A large valve is now in operation which offers a resistance of but 0.63 of a pound per square inch, or but one-tenth that just mentioned. This resistance is 382 per cent. of what is credited to the Lynn engine, and 85 per cent. of what, as stated, is required to lift the valves on the Lawrence engine.

The pumping engine which best meets the peculiarities of both steam and water is what is known as the Cornish engine, practically the Bolton and Watt single-acting engine. The advantages of this class of engine is that the indoor or steam stroke of the cylinder can be made quickly, and the outdoor or pumping stroke is made slowly, while the water is discharged as the weighted plunger settles; the steam passing from one end of the cylinder to the other, and forming an equilibrium during the interval between the steam and pumping stroke; and the connection with the condenser being made in the interval between the pumping and the steam-stroke. This form of engine is particularly useful in mines and shafts requiring long operating rods; and for general purposes, when a considerable

volume of water is to be elevated, it may be considered as the most economical and durable type of pumping engine. This may be deemed a bold assertion in the face of published reports of some late tests; but I am convinced that a Cornish pumping engine properly proportioned, constructed, and managed, will give, during its continued operation, equal if not superior economic results to any other form of pumping engine. One great advantage of this class of engine is the variety of speeds at which it can be operated. I have seen a Bull Cornish engine capable of raising 1,250,000 gallons to a height of 230 feet, operating satisfactorily at speeds varying from 20 strokes per minute to one stroke in three minutes.

That class of direct-acting pumping engines without flywheels, the "tappet pump," is, on account of cheapness and judicious presentation to the public notice, probably more popular than any other form at present. In their construction marked ingenuity has been employed, and where the work to be done is comparatively small, or the uses for which they are employed are of a temporary or supplementary character, they answer a very good purpose; but they do not prove to be either durable or economical in their operation.

In a recent defence of this class of engine, an attempt was made to demonstrate that a crank controlled by a flywheel and the motion of the piston or plunger of a pump, produce a constant damaging conflict of forces, which not only absorbs a large percentage of power, but also tends to destroy the machinery. The motion of the piston of a pump, produced by a crank with a flywheel of sufficient momentum to maintain a uniform velocity, is from rest at the "dead point," by accelerated velocity, to full stroke at 90 degrees, and from that point, by constantly diminishing velocity, to the opposite dead point, where there is sufficient rest to permit of valves seating themselves, and the direction of the water changing, the return stroke being from the "dead point" by accelerated velocity to 90 degrees, and thence, by decreasing velocity, to rest again. These so-called conflicting forces only come into play when a high degree of expansion is attempted with a single steam-cylinder directly connected to the pump; and hence one of the objections to the Cornish engine. To secure the full value of expansion it is necessary to use a flywheel, or other heavy moving part, to absorb the excess of power at the early part of a stroke, and give out power at the latter part of the stroke. Steam entering the cylinder of a Cornish engine strikes a blow (so to speak) upon the massive portions of the engine (which are constructed to receive this blow), and gives to the piston a mo-

mentum which is accelerated while the steam follows it, and then retarded as the steam expands, until the pressure of steam and weight of the moving parts are in equilibrium at the end of the stroke. Admitting, then, the conflict of forces, does not the value received by expansion more than neutralize any additional cost in the proportioning of an engine?

By using a compound engine and expanding from one cylinder to the other, and constructing the pumps in duplicate, a moderate degree of expansion is obtained with tappet pumps; but this duplication of parts is, in plain words, the construction and maintenance of an entire steam pumping engine in place of a simple and inexpensive flywheel, with practically no wear, or expenditure for maintenance.

Very superior engines, and those which rival the Cornish in economic duty, are constructed with compound steam-cylinders, bucket and plunger pumps, beam and flywheel, the compound cylinders in connection with the flywheel permitting a high degree of expansion.

Special conditions may make one form of pumping engine more desirable than another, but under ordinary circumstances, where a large volume of water is to be lifted to a considerable elevation, the superiority of well-proportioned and constructed pumping machines may be considered to rank as follows for economy:

1. Cornish, or single-acting engines.
2. Compound engines, with flywheel.
3. Condensing engines, with flywheel.
4. Compound engines, without flywheel, duplex pumps.
5. High pressure engines, with flywheels.
6. Condensing engines, without flywheel.
7. High pressure engines, without flywheel.
8. Rotary and centrifugal pumping engines.

It is hardly fair to place the rotary and centrifugal pumps among pumping engines requiring to be in constant service under heavy work, but they have been brought so prominently into notice that they deserve mention. The rotary engine and pump possess in theory so many apparent advantages that great ingenuity and much money have been expended in attempts to perfect a reliable apparatus.

One design proposed for mines demonstrated that the inventor had been so impressed with the rotary principle that he introduced obstructions in the delivery part of his pump, which, in connection with wings or blades on the revolving shaft, kept the water in a rotary motion regardless of the fact that all the power expending in rotat-

ing the water was entirely lost, so far as lifting it was concerned. Another inventor constructs his delivery pipe of a series of inclined planes, changing in direction every few feet, under the impression that water will ascend in a zigzag course with its increase of resistance more readily than in a solid vertical column.

This paper is, however, not intended to discuss particular machines, but only in a general way classes of pumping engines, and the above are introduced as instances of devotion to the rotary class. It is rather the principles of construction with which it is intended to deal, hence there is no reference of comparative duty tests. This I have reserved for future consideration, and shall be pleased to receive records of any pumping engines accessible to the members of the Institute.

In ascertaining the duty or actual commercial value of such an important machine as a large pumping engine, there need be no difficulty in arriving at an exact measure of comparative economy and merit, without resort to hypothesis or guessing at results. All the elements entering into the intelligent understanding of the subject are easily ascertained. They are,

1. Fuel actually consumed, with oil, packing, etc.
2. Weight of water delivered × height lifted × friction.
3. Reliability and durability.
4. Attendance and repairs.
5. Comparative first cost.

These facts can all be obtained and the results readily worked out to the satisfaction of any one interested in the operation of pumping engines. In some of the records of empirical tests there seems, however, to have been so much high art and scientific ability displayed that even to those with moderate attainments in mechanical engineering the *modus operandi* of securing the result is a mystery.

It has been claimed that the indicator is the best means of determining the relative value of pumping engines, for it tells the tale of the inside workings of a pump or steam-cylinder. Recognizing the value of indicator diagrams, I cannot conceive that they are as valuable in comparing various pumping engines as the record of the coal heap and the discharge weir. Comparisons by indicator diagrams are likely to be unjust unless they are taken with the same or a similar instrument, located in like positions on the various engines, and given in connection with the speed and work performed by the different machines. The contraction of water-ways, proportion and kind of valve also have a marked effect upon the appearance of cards

taken from a pump cylinder. While indicator diagrams are of great service to the engineer, and their comparison has done much to improve various motors, there are so many affecting causes to be considered that it is difficult to make satisfactory comparison of the records of different parties. A candid comparison of the elements proposed in this paper will give a just precedence to good engines, and I am convinced will sustain the relative order of merit as given.

THE USE OF ANTHRACITE WASTE.

BY JOHN F. BLANDY, M.E., PHILADELPHIA.

ALTHOUGH the question of the "waste of anthracite coal mining" has been so frequently discussed, and a committee was appointed at the first meeting of this Society to consider and report upon the subject, still but little progress seems to have been made in arriving at a conclusion as to how it can be reduced.

That committee made a preliminary report at the August meeting, 1871, in which it divided the question into three parts, namely: Waste in mining, in preparing for market, and in transportation.

I shall not here refer to the first item, as so much depends upon the peculiar features of each separate mine, and the skill of those in charge; but in reference to the second, that of preparing the coal for market in breaker and screens, I wish to make some remarks. There is no use considering the question, whether the coal *should* be broken up to suit the fancy of consumers; all miners are satisfied that it should not be, but the consumers decide that they want it that way, and the miner must submit, and simply utter his maledictions upon the head of the man who first suggested a breaker or screen, if that is any consolation to him.

What is called *waste* in this process of preparation, is the *dust and fine coal*, which results from the breaking and screening, and, as we all know, this is a very important percentage of what passes from the slope to the top of the breaker. Now, if this dust and fine coal can be utilized—the slate which is picked out is not to be taken into consideration as waste—then we get rid of this item entirely. There is no question in my mind that this article can and will be used as a steam generator at least, and I think, therefore, that in depositing

it away from the screens care should be taken to keep it separated from the slate which has been picked out, so as to avoid at some future day the necessity of rescreening it. At present the practice is to dump it wherever it is convenient.

Many attempts have been made to burn this material, by mixing it with portions of clay, with fine bituminous coals, or other materials as a cement, and pressing it into blocks, etc., none of which, at the present time, can be really pronounced successful—that is, sufficiently successful to be generally received as practicable—either from the fact that they are too expensive to compete with the coarser coals, or because the apparatus for using the fine coal is too complicated for the general workman.

I wish to call attention, however, to one exception in this list of trials, which is probably not known to many of our members, and has probably been forgotten by others. I refer to the "Braun furnace," which has been very successful in several instances, and, from my own experience, very economical.

In the year 1867, I examined one in use in Cortlandt Street, New York, and one in Brooklyn, both of which had been running for some time upon anthracite dust, with a small admixture of pea coal, gathered from the city coal yards. Being at that time in charge of the mines at Tamaqua, Pa., I examined these two furnaces carefully, and received such satisfactory accounts of them that I determined to try them at the Newkirk colliery. This colliery was worked out at the first lift below water level, and as it was connected with the adjoining collieries, I was obliged to keep the water out of it. Wishing to arrange all upon as economical a basis as possible, I thought that if I could manage to run the pumps by the use of the dirt from the screen-banks, I should attain the object very successfully. For this purpose I set four plain cylinder boilers—30 inches diameter—in pairs, with a Braun furnace to each pair—the furnaces being side by side, with a partition wall. I arranged the double chamber under the boilers with the special purpose of thoroughly consuming the gas. There were two 12-inch plunger pumps, driven with gear wheels, and with a lift of about 250 feet perpendicular height. The result was a success, as I ran the pumps continuously for about eight or nine months—until the close of my superintendence—without any stoppage for repairs to the furnaces. How much longer they were in use I do not know. My successor in office took them out, but for what reason I never learned. During the time they were in

my charge, no other fuel was used than that which was hauled in from the waste heap of the mines.

As the coal-beds at that time were much troubled with "*dirt faults*," the character of the "waste heaps" was by no means of the best, and far from pure coal. The result was such as to fully satisfy me that all the engines about an anthracite colliery can be run upon this material, and, therefore, the small coal which is now used for that purpose could be sent to market. Certainly in this way a large amount of what is now called *waste* could be avoided, and if successfully and generally used at the mines, it would soon find its way into use elsewhere. The question resolves itself, therefore, not into one of preventing the making of dust and fine coal, but into one of how to consume it when made.

The furnace, as then constructed, is open to improvements, especially in the method of feeding the fires, but in its main features it is correct, easily managed, not nearly as laborious as the ordinary fire, and little liable to repairs.

In the ordinary construction of the fire-box of stationary boilers, the main item of cost for repairs is in grate-bars, as in burning the refuse and small coal at anthracite mines there is such a large amount of hard cinder and clinker that the bars are soon destroyed. In the Braun furnace this is not at all the case, as I have seen bars taken from it, after many months of use, that were as good and clean as when put in new. The reason of this is that the hot coals—if the fire is properly handled—never come in contact with the bars; they act simply as screens to let the ashes through—care always being taken to leave them covered with a good bed of ash, which can be easily done without interfering with the draft. The main feature of the furnace is the vaulted fire-brick roof over the fire, which, acting as a reflector of the heat, keeps the top of the coal in a glow, and as the draft can be admitted through the doors equally as well as through the grates, the slight draft through the bars prevents the forming of hard cinder. By the proper regulation of the draft over the fire a more perfect combustion of the gases takes place.

The whole construction of the furnace is very simple, and any ordinary workman can soon be taught to handle it. I cannot now tell the cost of it, but it is but little, if any, more than the ordinary method. In these respects it commends itself to general use, and, as I stated above, there should be no trouble in its adoption, at least at all the mines.

The result might be that many improvements might be made upon it or furnaces of a similar construction, and the final result be the elimination of this item of "waste in preparation," and a great benefit attained for both landlord and tenant.

ATLANTA DISTRICT.

BY JOSHUA E. CLAYTON, SALT LAKE, UTAH.

THIS remarkable gold and silver bearing district is situated on the middle fork of Boise River, in Alturas County, Idaho Territory, about eighteen miles north of Rocky Bar, and sixty-five to seventy miles, as the crow flies, east of Boise City, the capital of the Territory. This district lies in the very heart of one of the most wild and mountainous regions of Idaho. For many miles in every direction nothing can be seen but bold granite mountains, with deep narrow gorges cutting into their sides in every direction, rendering them almost inaccessible except to the hardy mountaineer and adventurous prospector.

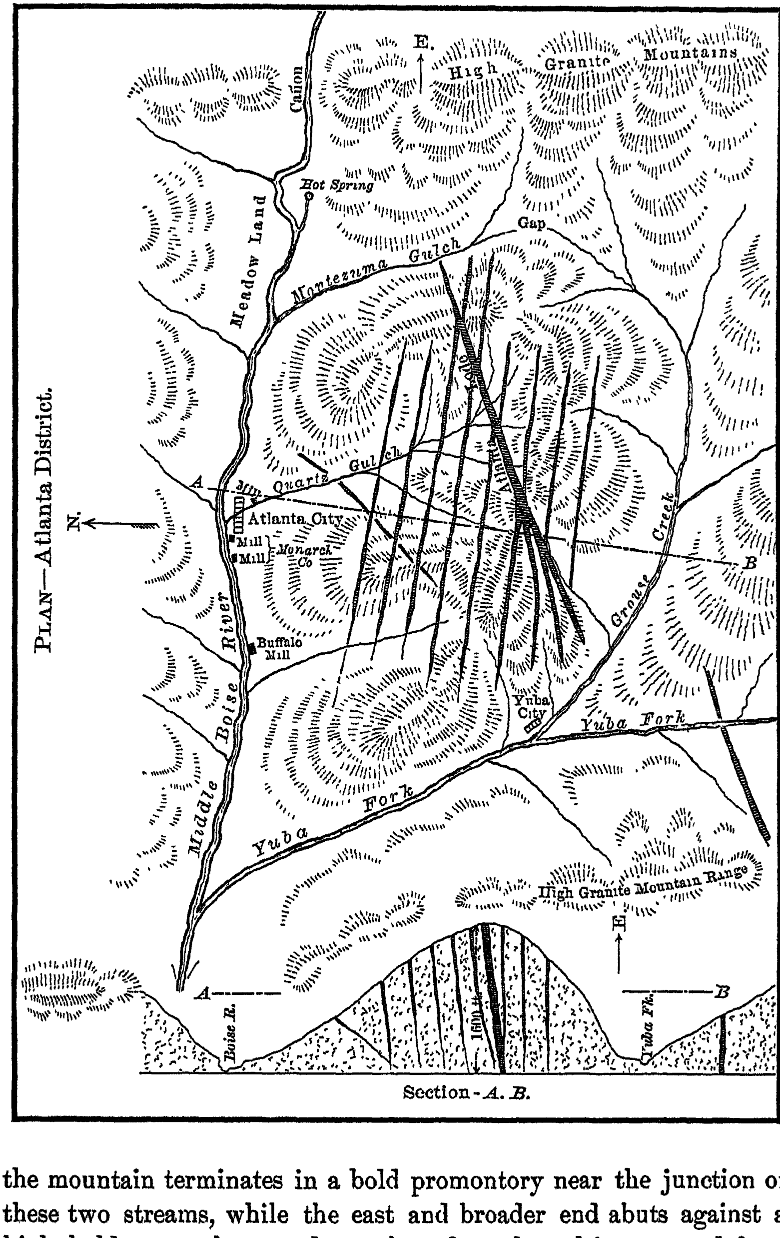
The mountain sides are covered, in most part, by dense forests of pine, fir, and spruce timber. In every cañon there are clear streams of pure running water that empty into the principal forks of Boise River.

The only line of approach to this mountainous region at present is from the southwest, by way of Rocky Bar, the county seat of Alturas County, to which place there is a good wagon-road. From thence to Atlanta City, eighteen miles, the road, or pack-trail, passes over the high, steep range that separates the south and middle forks of Boise River. During severe winters this line of approach is closed up by deep snows for months at a time, thus leaving the district isolated, in the bosom of the grand old mountains.

The geological formation is granite, of a coarse, friable texture, and in many places is traversed by numerous dikes of syenite, and three or four varieties of porphyry, which cut through the granite in easterly and westerly directions. The metal-bearing veins also have an easterly and westerly trend, but are occasionally intersected by the dikes.

The largest number of the gold and silver lodes are confined to a

partially isolated mountain, lying between Middle Boise on the north and Yuba Creek and its tributaries on the south. The west end of



Section - *A. B.*

the mountain terminates in a bold promontory near the junction of these two streams, while the east and broader end abuts against a high, bold range, that trends north and south, and is separated from

it by a low depression called Montezuma Gap. (See accompanying sketch.) This partially isolated mountain is commonly called "Atlanta Hill," and is surrounded by mountains much higher than itself, giving it the appearance of a hill in the centre of a grand amphitheatre of lofty granite mountains.

Its dimensions are about four miles long from east to west, by two or three miles wide from north to south. Its height above the river at its base is about 1600 feet, and above the sea level 6700 feet. Atlanta City on the flat near the river at the north base of the hill is 5200 feet above sea level.

The vein system consists in most part of a series of nearly parallel veins, having a course of N. 80° W. and S. 80° E., magnetic, with a dip south 60° to 80° below the horizontal line. The number of these veins is not accurately known, but on the north slope there are four or five which have been worked to some extent, and on the south slope there are at least three that have been located and proved to be gold-bearing. The lodes in this system of veins are generally small, varying in thickness from one to six feet or more. They all carry free gold in occasional chimneys or shoots, with barren spaces between them. They are all in true fissures with well-defined walls and clay salvages, showing lines of nearly vertical movement. But the great feature of the district is the Atlanta Lode. This is an immense lode, that has a course about north 70° east, and south 70° west, and cuts obliquely across all the others. It has a dip south, of 60° to 70° below the horizon. Commencing on the north side of Montezuma Gap, this great lode cuts through the hill obliquely, crossing the summit at a point about 6000 feet westerly from said gap, thence continuing its course obliquely down the southwest slope of the hill, towards Yuba Creek, a distance of four or five thousand feet. Before reaching the southwest base of the hill all trace of the vein is lost. The total length of the outcrop is about two miles, and, as the character of the granite country rock changes near the east and west ends of the outcrop, I think it probable that the vein does not extend much beyond the limits of the outcrop.

The entire length of this lode has been located, and enough surface work done to hold the claims under the law. The only developments made of a permanent character are on the Monarch and Buffalo claims on the north slope of the hill. Both of these claims have been tapped by tunnels run from Quartz Gulch, cutting the vein about 100 feet below the surface, and, say, 80 feet below the water line.

The Monarch tunnel gains depth as it goes east along the lode into the ridge towards Montezuma Gap. At the east end of this ground the depth will be about 300 feet below the surface. The width of the lode between the walls varies from 40 to 100 feet or more; at the point where it crosses the summit going west it is much wider, but its exact limits are not known. This wide portion at the summit is called the "blow out." West of this point the lode divides into two or three main fissures down the southwest slope of the hill.

The vein structure or gangue is quartz, with inclosures of granite in the form of "horses," some of which are very large. The structure of the quartz is somewhat granular and friable, very much like that in the Comstock Lode.

The metallic contents are gold, native silver, ruby silver, brittle silver ore, and sulphide of silver. The brittle silver, or black antimonial silver, is the most abundant ore. Next in quantity and value is the ruby silver. The native silver and silver glance are found only in small quantities. The free gold constitutes from 20 to 40 per cent. of the total value. The other minerals are iron pyrites in moderate quantities disseminated through the granular, friable quartz, and the granitic inclosures of the lode. I saw but little traces of copper, zinc, or lead. In fact, this lode carries the purest ores of silver that I have ever seen in any extensive mine.

Much of the quartz in this lode is comparatively barren. The rich streak of black sulphuret and ruby ore varies in width from one foot to six or seven feet, and alongside of it is a zone of pay rock equally as wide that carries a good percentage of free gold with silver ore disseminated through it, making the pay streak from two to fifteen feet wide, and extending in length underground in the Monarch and Buffalo claims nearly two thousand feet on the course of the lode.

No rich silver ore has ever been found on the surface outcrop of the lode; occasional bunches of rich gold-bearing quartz have been found, and the surface dirt along the entire length of outcrop contains free gold. I could not find any distinct traces of chloride of silver anywhere on the lode. The country rock is a very old granite, that does not carry chlorine, hence no chloride of silver has been found in the exposed portions of the lode. In fact the croppings appear to have been impoverished by oxidation and leaching out of nearly all the silver above the water line.

The oxidation of the sulphuret of silver changes it to a sulphate, which is soluble in water. Where chlorine is present it becomes

fixed as an insoluble chloride, but where it is not present the sulphate dissolves and goes out with the surface water, or else settles down in the lode to the water line and redeposits as a sulphide, or as native silver if the proper chemical reagents are present. This, I think, is the true explanation of the absence of rich silver ore in the croppings of the Atlanta Lode.

It does not follow that the lode carries rich silver ore below the water line throughout its whole length. If it did, it would be a remarkable exception to the general rule. The probabilities are that there are a number of rich chimneys in the lode, with poor or even barren spaces between them; but as the rich silver ore does not come to the surface, the position of the rich ore bodies can only be ascertained by underground explorations. As a rule, however, those portions of the outcrop that carry the most free gold will be the richest in silver below the water line.

The water stands in the lode very near the surface. This is owing to the character of the country rock, a softish granite with all the seams filled with clay, thus holding the water in the lode very near the surface, except where ravines cut across it so as to drain the water endwise into such ravines. Even along the line of the vein the water does not escape readily, for the reason that the joints and seams in it have been filled with clay by infiltration so as to hold the water very near the surface. For this reason the water line in the Atlanta Lode is not a horizontal line, but one closely approximating to the surface profile of the lode.

There are many details of an interesting character that cannot be embodied in this paper without taking up too much space. My present aim has been to give a brief outline description of the district, and the great lode which is its most striking feature.

My reasons for calling this a very *old* granite are based upon two comprehensive facts: 1st. I could find no trace of bedded structure anywhere in the surrounding country, except some gneissoid granite that *may* be archean; and 2d. I observed four or five varieties of trapean and porphyry dikes that belong to the older *hornblende* traps rather than to the porphyritic series.

The absence of chlorine in the croppings of the silver lodes is another proof that these mountains have been above the sea level since very remote periods, possibly as far back as the archean age.

All the silver lodes of the West having any connection whatever with marine beds—however remote in geological age—show chloride

of silver in the oxidized portions of the lodes near the surface. Even in granite districts, where the silver lodes do not come in contact with marine rocks, we often find chloride of silver in the croppings, but in every such instance I have found proof of the upheaval of the granite through marine beds, some of them as late in geological time as the cretaceous age.

THE NORTH SHORE OF LAKE SUPERIOR AS A MINERAL-BEARING DISTRICT.

BY W. M. COURTIS, M.E., WYANDOTTE, MICH.

THIS district commences near Pigeon River, the northeastern boundary between Minnesota and Province of Ontario, and extends entirely around the north shore of Lake Superior, terminating for the present at the Bruce Mines on Lake Huron. The discoveries of mineral-bearing veins have been confined for the most part to the lake shore, or to the country opened up by the Dawson Red River road. As yet the country back from the lake has been but little explored, on account of its roughness, being intersected by steep, rocky trap bluffs, 1000 or more feet high, and alternating white cedar and tamarack swamps. The forests are exceedingly difficult for prospectors. In many places Titanic piles of rocks, protected by *chevaux-de-frise* of dead cedars, with their hooked, tough, sharp branches, and a covering of spongy moss, sometimes several feet thick, successively guard against the discovery of hidden treasure.

The Hudson's Bay Company for nearly a century have maintained trading-posts at Fort William and other points, which probably opened the way to the first discoveries that were made at Prince's Bay, near the western limit of the district. At this point a large vein was worked by Colonel Prince, the owner, as early as 1846. The richest part of the vein seems to have been on Spar Island, but work was stopped on account of excess of water. Sir William Logan states that a mass of ore weighing several hundred pounds and carrying 3 per cent. of silver was taken out. On the mainland small quantities of native and sulphide of silver were found, together with iron and copper pyrites, zinc blende, and galena, in a large spar vein. On the main shore a drift 165 feet long and 90 feet in depth

was run, but apparently with the same success that has attended nearly all the mining enterprises yet undertaken. About this time the Montreal Mining Company employed Prof. Forrest Sheppard to locate lands on Lakes Superior and Huron. During the summer of 1846 he had located eighteen blocks, two miles by five, including Jarvis and Silver Islet, although not then known to have silver-bearing veins.

This company spent considerable money on some native copper locations on St. Ignace, but finally turned their attention to the Bruce Copper Mines on Lake Huron. These mines have been worked with considerable though waning success until last year, when a disastrous cave put an end to the operations. I have heard that some explorations are being made on other veins at this point.

About 1863 attention was again called to this district by discoveries at various points, and each year to 1868 was marked by fresh developments.

Walbridge & Co. worked a location near the Kaminstiquia River, about seven miles from Fort William, during some months in 1863, their aim having been to sell the property as a copper mine; about one ton of copper pyrites ore was obtained for specimens, and zinc blende and galena were also found.

Before speaking of the different discoveries I will say a few words in regard to the geology of the district, which I take from an excellent article that was read before the Canadian Institute of Toronto, by Mr. Peter McKellar, of Fort William, one of the most successful scientific explorers of the district. This article has been published in pamphlet form under title *Mining on the North Shore*, and contains a full history of each location, although many exaggerated reports are given as facts, because they come from supposed trustworthy sources, and some extravagant hopes have not been fulfilled.

The geological formations of this section are: The Laurentian, Huronian, and the Upper Copper Rocks, described by Sir William Logan, Profs. Bell and Chapman. The Upper Copper Rocks are supposed to be the equivalent of a part of the Lower Silurian, and are divided into two divisions, the upper and lower beds.

The Laurentian Rocks.—This series occupies the "Height of Land" principally, touching the Lake Shore in but few places within the district. It consists of granite, gneiss, syenite, and micaceous schists, almost entirely. Its veins of quartz and spar carry copper and iron pyrites, also galena and zinc blende occasionally. Mr. McKellar's

experience is unfavorable to the metalliferous qualities of these rocks.

The Huronian Rocks.—This series lies generally between the Silurian and Laurentian, striking occasionally in a northeasterly direction, in a broad belt or trough, back toward the Height of Land into the Laurentian. The principal area occupied by these belts stretches westward from Thunder Bay through Shebandowan Lake, on to the American boundary. It consists of greenish and greenish-gray strata, with a dip nearly vertical. The principal portions have a slaty structure, consisting of chloritic, argillaceous, talcose, silicious, dioritic, and fine-grain micaceous slates, with interstratified beds of massive diorite.

3 A Mine, Jackfish Lake Gold and Silver Mine, Heron Bay gold and silver, Partridge Lake gold lode, west of Mille Lac, together with lodes opposite Slate Islands, are all in this formation. Gold seems to be a characteristic of these veins, while the silver, from the next formation, is absolutely free from gold, no trace being obtained from 70 grams of Silver Islet silver or 20 grams of Duncan silver.

The Lower Beds of the Upper Copper Rocks.—These come next in ascending order. They occupy the coast and islands, with the exception of two or three pieces near Silver Harbor, where the older rocks come in from the east end of Thunder Bay westwards on to the American territory, showing also at a few points further east underlying the upper beds.

They consist of layers of chert, dolomite, and iron ore, the latter being near the base, with thick beds of clay, slate, and gray argillaceous sandstone shales, interstratified with beds of columnar trap.

The intersecting veins carry silver, galena, zinc blende, and copper and iron pyrites, and other metals, and niccolite at Silver Islet.

Silver Islet, Thunder Bay, Duncan (or Champion lode), Silver Harbor, Prince's Bay, Spar Island, Jarvis Island, Pie Island, and many other locations are all on silver-bearing veins intersecting these slates.

The Upper Beds of the Copper Rocks.—These occupy the principal part of the coast, and almost all the islands from Thunder Bay to the east end of Nepigon Bay. They consist of sandstones, conglomerates, indurated marls, and some interstratified soapstone, crowned by an immense thickness of trappean beds, most of which are amygdaloidal in character.

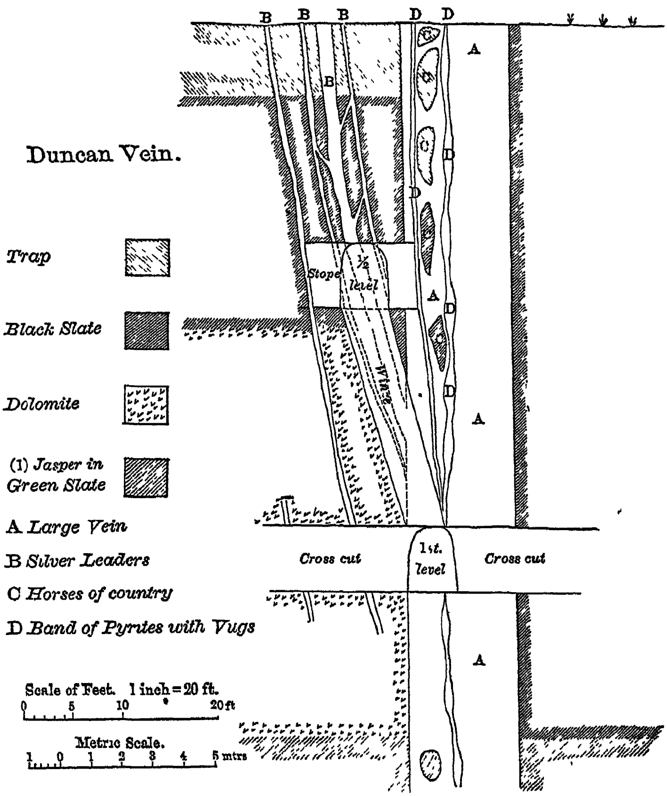
The quartz and spar veins which traverse the sedimentary or lower

portion hold galena, copper ores, and zinc blende in very considerable quantities, also gold and silver, as at the Enterprise Mine, Black Bay. The Silver Lake, Cariboo, and the above are the principal lodes known in these strata. The above trappean beds are the famous native copper-bearing rocks of the South Shore and Isle Royale. At the former place the workable lodes conform with the strata dip at a high angle, and are of well-known richness. On the North Shore these rocks dip at low angles. Native copper with associated nuggets of silver is the principal metal found in these rocks, but occasionally the sulphurets and other ores are met in small quantities. The veins, in passing through them into the sandstone, seem to drop the native copper, it being replaced by the sulphurets. Many years ago the Montreal Company and others spent a considerable sum of money mining in these rocks without success, but that is of little importance, as there were ten times more spent on the South Shore before the mines proved productive. At the Minong Mine on Isle Royale extensive ancient workings have been discovered, and large masses of copper, some 30 tons of mass copper, were obtained last summer.

The veins have not yet been opened sufficiently to give a reliable theory for the deposit of silver in them, but as Mr. McDermott, in an article in the *Engineering and Mining Journal*, vol. xxiii, Nos. 4 and 5, on the Silver Islet vein, proves, the deposit of silver in the veins has been directly connected with some form of carbon in the country rock. Graphite is found at Silver Islet, anthracite at Duncan, and also by Mr. A. B. Wood on the east side of Thunder Bay. Manganese seems to be closely associated with the silver in different forms for different veins. I have noticed that an opaque milk-white spar carries galena and blende with very little silver, while yellow, brown, or rose-colored spar carries native silver and mineral rich in silver. The description of one vein will answer for all that have been opened to any depth.

The veins consist of one main fissure, with many parallel fissures rising from the foot-wall at different depths, and at some places striking into the main fissure, afterwards continuing as separate fissures again. These small fissures seem to be the silver-bearing part of the vein, and the large fissure is silver-bearing only in the neighborhood of these junctions. Where the main veins branch appears to be the place where the largest deposits of ore are found. Silver Islet, Thunder Bay, Duncan, and 3 A, the richest mines now discovered, are at a fork of the main fissure. All these veins carry ore in the

leaders (B, on accompanying sketch), rising from the foot-wall and running more or less parallel to the main vein. The ore is in bunches, with ground almost barren between. The sketch shows the Duncan vein, cut in section at its eastern extremity. At the western end, the dolomite, which here has been cross-cut 88 feet without finding the end, is only about ten feet wide on the cross-cut at that point;



then come the silver leaders, and then black slate. The leaders at that point enter the large vein below the first level instead of above, as on the section, and some of the largest branches of ore were found here. The silver seems to give out as soon as the leaders enter the dolomite. A is main vein, with leaders, B. D is a band of iron pyrites and fluorite, more or less branching at the surface. The vein at this band has large vugs, elongated in the direction of strike of vein, filled at Duncan with water, but often with gas at Silver Islet. They are often ten or more feet long, containing calcspar crystals up to 100

lbs. weight. The vein contains horses of the country rock, trap horses being found below the line where it forms the country rock. These horses have been in part metamorphosed, shown by the black slate horses, which have a specific gravity of only 2.542 against 2.719, the specific gravity of the same slate just outside the vein. The edges of the fissures are often brecciated, carrying native silver or ore, as do also many of the black slate horses in the main vein, deposited on the surface of the slate, probably reduced by the action of the carbon of the slate.

The principal gangue, almost *the* gangue, is calcspar. The lime sometimes is replaced by magnesia or manganese. At Silver Islet the latter makes the spar pink, perhaps passing into rhodochrosite. At Duncan there is no pink spar, but it is colored amethyst, and cavities near the surface are filled with black oxide of manganese. The quartz of this district is often amethyst. Most of the veins on the mainland yield fine specimens, especially the amethyst vein at the foot of Thunder Bay. Quartz is the second mineral in importance in the gangue. Fluorite and heavy spar enter largely into the gangue of some veins, while in others they are in very small quantities or unnoticed. The minerals are native silver, argentite, zinc blende, galena, iron and copper pyrites, and a few rarer minerals. At the different veins sometimes one or the other mineral will form the principal part of the ore, while the others will be more or less suppressed.

The Country Rocks.—The trap is diorite. The Macfarlane Band is a coarse-grained light-green diorite. As this band contains some of the first known veins it was supposed to be *the* mineral producer, but later work makes this decidedly doubtful. 43.6 per cent. of this rock is insoluble.

The black slate has a specific gravity of 2.719, is fine-grained, gives off no water on ignition, is barely fusible on the edges to brown glass and leaves a residue of 83.1 per cent. insoluble in acid.

The greenish-gray slate has a specific gravity of 2.775, contains light-green microscopic crystals, gives off much water on ignition, is quite fusible to a black glass, and in acid leaves but 53.4 per cent. of residue. This slate incloses lenticular masses of chert in the upper part of the bed of a red color, in lower part gray.

The dolomite between these slates contains bands of silver, and shows a trace of manganese, sometimes little pockets of anthracite where it joins the black slates. All the country rocks are more or

less impregnated with iron and copper pyrites and galena, even at a distance from the veins, mostly in microscopic crystals.

In 1866 the Thunder Bay Mine was located about five miles from Prince Arthur's. An English company spent some money in exploration and machinery, but with very little success. There was a splendid show of native silver on the surface, but it soon gave out. About 3294 lbs. were taken out, worth $2592, besides specimens, and possibly as much more was stolen. This mine was opened in 1874 again with about enough money to put it in working order. There being no money to carry on the explorations, it was closed down again without result. There is a fine vein here that should be prospected by a shaft 1000 feet deep if necessary, and perhaps some result would be obtained that would answer the question for the whole district.

Nature has most kindly aided the wild-cat speculator in this district, and he has not been slow to accept her proffered bounty. Attest a long list of mines with $1,000,000 to $2,000,000 in capital stock, one-fifth paid in, mostly into the pockets of the speculator. At the surface, small pockets of beautiful native silver ore are found furnishing specimens, and a few barrels of ore bringing $1000 to $10,000, which enables the ring to get safely out. The stockholders then examine, find the pockets exhausted, sink perhaps one hundred feet in the barren ground, and retire in disgust on account of the slow progress and great cost of the work. The cherty slates are very difficult to work, and the large, barren vein is usually both wet and too soft to break well. With a fine party of nine miners, but 11 feet could be made per month in an 8 x 10 shaft. At the Duncan Mine an effort is being made to pass this barren belt in the hope that in a more favorable country rock the vein may prove productive. They have sunk 250 feet in the barren belt, and at that depth have passed, apparently, the hardest of the ground, and are now making quite rapid progress, with every indication that success will come soon, if the silver bodies are not entirely confined to the surface, which is not at all likely, especially as the minerals of the vein have gained slightly in silver, containing now about four ounces per ton in the mineral free of gangue. The Duncan Mine was discovered in 1867, and is one location of the Champion lode, an immense spar lode running nearly east and west with an almost vertical dip. On this same lode are the International, Caledonia, Ontario, Algoma, Dog Lake, Ontonagon, and North Shore. At the Duncan alone has any silver been found, except a very small amount contained in the

galena or zinc blende. Sulphide of silver has been reported at all the locations, but I have never seen any, and think the parties were deceived by films of other minerals on the spar.

The reason of this is that Duncan happens to be on high land, and has the hill capped with black slate, while the other locations are in the greenish slate, in which Duncan is practically barren. The International has probably some silver, as the black slates pass on to this property, but no explorations have been made in them. The value of all these locations depends on whether Duncan finds a silver-bearing zone below the barren slates. All the reports that Duncan had struck silver below 70 feet were false, though Mr. McKellar gives two such reports. In January, 1877, however, plumbago was struck at a depth of 315 feet. As Silver Islet is rich only where the rock carries plumbago, and is somewhere between 316 and 330 feet below Duncan, the indications are certainly worthy of being followed up, and the chance of success is good.

The total value of ore produced to date at Duncan is about $15,000, and about $150,000 has been expended. The richest ore has assayed in bulk 2020 ounces, the poorest concentrations 73 ounces; as about 60 tons are concentrated into one, the original stamp-rock is often pretty poor. In some parts, especially near the surface, the stamp-rock has assayed 6 to 8 ounces, taking out the whole rock for 6 to 12 feet wide. These rich places also gave some hundreds of pounds of very rich ore. Specimen 10 is the richest ore, 4 is stamp-rock, and 11 is the very rich argentiferous zinc blende found only at the surface. Although large quantities of zinc blende are found below 70 feet, it contains only a trace of silver.

In the winter of 1867 the government placed on all patented land on Lake Superior an annual tax of two cents per acre. This led the Montreal Mining Company to explore the lands located by Prof. Sheppard, and Mr. Thomas Macfarlane was placed in charge of the surveys. His first discovery was on Jarvis Island, about 22 miles south of Fort William. Some little work was done here, opening up a large spar vein. With the exception of some small lots of rich ore, nothing important was found. This property passed into the hands of the Silver Islet Company, and was by them sold for $150,000 to an English company. They spent considerable money in exploring the vein, but the little pockets of rich ore did not produce sufficient returns to warrant a continuance of the work. The difficulty with all the North Shore veins is that the ore is so uncertainly distributed in them, and they are so very large that a great

deal of dead work can be done, and yet no bunches be found. At the Duncan the drift had passed within two feet on one side, and a slope a few inches on the other, taking out everything that looked like ore, yet an accidental blast in the pillar standing threw out $300 worth of rich ore, and succeeding blasts produced as much more in rich ore and stamp-rock.

Mr. Macfarlane next turned his attention to Wood's location on Thunder Cape. He accidentally went to the little rock, now called Silver Islet, to examine the diorite dike, and then discovered the silver vein that has given this district its interest.

There is no need of describing Silver Islet, as it has already been described by Mr. McDermott and others, in articles above referred to. Mr. Macfarlane, unable to get the Canadians to raise the necessary money to carry on the work, in spite of the fact that many thousand dollars' worth of ore had been taken out, succeeded in interesting parties from the States. These parties bought all the lands of the Montreal Mining Company, and a capital of $73,000 paid a dividend of $160,000 the first year, besides paying about $200,000 towards settlement with the Montreal Mining Company, and expending also a large amount of money to establish the plant.

In the report for this year we find that the total amount of dividends have been $622,666.66, and the total production $2,237,479.84. The great outlay was needed at the mine to establish a town on a barren rocky shore; to maintain a foothold on a little rock not 80 feet square against the mighty storms of Lake Superior; to furnish steam-tugs, engines, pumps; and build a mill capable of concentrating over 75 tons of rock per day.

Silver Islet stands to-day perfectly equipped for mining, concentrating, and smelting 50 to 100 tons of ore per day. It has immense tracts of land in a mineral district that has hardly been explored as yet. It has nearly $700,000 worth of property on hand and only $400,000 indebtedness, and its own vein has been explored only about 800 feet deep and 600 feet horizontally. Yet to-day its stock is almost valueless. The cause of this has been the failure to find a second pocket of ore in depth that promises returns. Small amounts of ore have been found by the drill at different depths. It is the present intention to push the deep shaft 400 feet deeper and explore to the southward, which is the supposed direction of the dip of the silver bodies.

The failure of Silver Islet to produce even expenses for the last two years has dampened the ardor of other mining companies, so that with the exception of very feeble efforts at other points, except

Duncan, the results of whose development all interested are watching, there is no extensive mining being done. Specimen 13 shows the richest ore, assaying 4000 ounces to the ton, and No. 14 a poor piece of No. 2 ore, interesting only as showing the gangue.

The average assay of all ore smelted from Silver Islet during the first three years was above 900 ounces per ton. It is difficult to come down from the meteoric splendor of Silver Islet to chronicle failures at other points, but such must be the case. I shall mention only those veins where some mining has been done.

In the summer of 1870 the Beck or Silver Harbor vein was found, on the west side of Thunder Bay. It is eight or ten feet wide, and differs from others in the amount of quartz in the gangue. The silver here was found in nuggets of sulphide and considerable zinc blende. Fine buildings were put up and some mining done. For smelting 125 barrels were shipped, which, either through fraud or ignorance of the manager, was reported to be worth $300 per barrel, but which proved to assay $17 per ton. There is without doubt a large amount of ore at this mine that will pay for treatment when the owners have recovered from the shock of the first disappointment. Some miners from Silver Harbor discovered on the adjoining property a vein carrying native silver and niccolite in a small vein with many parallel fissures. Some few tons of very rich ore were taken out, probably about $10,000 worth in all at the highest figure. The average of this ore contained 4½ per cent. of nickel and some cobalt. These veins were in the Huronian talcose slates, which are very easy to explore, so that considerable work has been done. At about 140 feet the vein pinched out, and work was stopped, the capital being exhausted and the stock unassessable. I believe this property promises better than any other that I have seen. As the vein was small the rich ore was picked out clean, so I do not think the dumps are worth the cost of concentrating. The surface of this property has been but little explored. It is very probable that there are other surface pockets perhaps large enough to pay large returns. Not far from this location is a vein of milky quartz that carries native bismuth, and also shows a little silver on assay. This vein has been traced two miles, is about 2 feet wide, dipping about 40°. Nothing but a few shallow pits have been opened. The bismuth was at first taken for native silver, and a trial pit was put down twelve feet. A few kegs of bismuth specimens were taken out, and then the fact discovered that the metal was bismuth, and the amount of silver it contained was insufficient pay. But little of the vein is exposed, and

nearly all the specimens taken away. I succeeded in breaking off a few chips for assay, but have no specimen. The character of the vein is so promising that I have no doubt at some future day, when some one of the apparently barren veins has proved to be rich, this one will be explored by drill or otherwise.

The vein on Pie Island, at the mouth of Thunder Bay, was opened in 1875 by a shaft 60 feet deep, and a small quantity of rich ore taken from a small stringer. The main vein carried galena and zinc blende, very poor in silver, and no nickel, which metal had accompanied the rich native silver ore of the stringer. The vein action on this island has been very extensive, but as yet little exploration has been done. The work was stopped on account of financial difficulties. The fact that bricks estimated to contain 20 per cent. of silver were shown as products from the ore, but which proved to be very impure lead without any silver, throws discredit not on the mine, but the person in charge. Where there are so many promising veins, and it is so easy to obtain rich specimens, the temptation to "salt" has been great and has had its effect. The most famous swindle was the Tin of Otter Head. Here a vein was picked out, and then the fissure filled with artificial stone mixed with rich specimens and washed tin ore. The brook at convenient points was also well salted. Then the "childlike and bland" explorers carried a few barrels of specimens of a stuff they had found at Otter Head to different assayers, calling it iron ore. Its true character was soon discovered. Practical mining experts (so-called) were sent to look at it, and reported very favorably on the "find," explained perhaps by a big spree well planned. The capitalists took hold, and parties were sent out to locate lands. A gentleman in one of these parties detected the fraud, and the bubble burst. In 1872 and 1873 many specimens were sent for assay that proved exceedingly rich in gold and silver. Also others containing gold, silver, nickel, and cobalt, in an ore, any one of the metals in large quantity. The first proved to be specimens from Jackfish Lake at Shebandowan, about 45 miles from the lake shore. Native gold was found, and Mr. McDermott first noticed the presence of sylvanite as one of the gold minerals. Although very rich hand-specimens are obtained, the ore in bulk is not very rich, but will probably give good working results. Almost all the pyrites from this district will contain a little gold, from a trace to $12, and some silver. The character of the ore can be seen from the specimens, though no native silver is to be seen.

Trouble with the Indians, whose title to the land had not been

extinguished, prevented these mines being opened at the time, and dull times since have kept this district undeveloped. Last summer the first location was put in condition to be reported upon by stripping the vein for over a mile. Some fine specimens of native gold were found. The ore containing cobalt and nickel came from Héron Bay, where there is said to be a very promising vein. A little work was done, but trouble arose among the owners, so nothing more can be done until settlement. The specimen ore was certainly very rich, carrying about 1000 ounces silver, one or two ounces gold, and nine or ten per cent. of cobalt and nickel. I understood the average was about $140 to the ton.

Black Bay.—The veins of Black Bay were discovered as early as 1865. They are mostly base metals, galena, and copper pyrites, and considerable heavy spar in the gangue. The Enterprise Mine has done a great deal of surface work, building a tramway to the lake and putting up good buildings. On the vein there has been considerable work, but the result has been poor.

The vein at the surface was six to eight feet wide, the solid mineral band in it was three to four feet, but on sinking the mineral gave out, and the vein broke up into stringers. A shaft 100 feet was sunk last winter in the hopes of finding a continuation of the ore body, but without success so far as I can learn. An average of several tons of ore gave silver $10\frac{2}{10}$ ounces; gold, $\frac{1}{2}$ ounce; copper, 1.89 per cent.; lead, 38 per cent. There are other veins here that produce large masses of galena nearly free from gangue.

The duty on lead and lead ores in the United States has prevented these mines from being worked by small companies, and the poverty of the ores in the precious metals and the uncertainty of the veins have prevented larger companies putting up the necessary furnaces.

Other veins have been found near Duluth that produce ore like Specimen 20, which at first appearance could easily be mistaken for rich ore. It contains but a few ounces of silver per ton, being galena and zinc blende. At the Little Pic, at the east end of the lake, Mr. McKellar has been opening a large vein during the past season, containing zinc blende and galena. The ore as mined is poor in silver, the specimens assaying about $10. If these specimens are crushed and the galena washed out, it will assay about $100. There are streaks of galena in the vein that give this higher assay. Ore from another vein at this point assays 32 ounces in bulk, but the

washed galena will assay $300 per ton. Nothing but prospecting has yet been done.

The latest discoveries have been from Pigeon River, and very fine specimens of native silver have been shown as coming from there, and I believe it is really a *bona fide* discovery. Some parties from St. Paul are opening a vein at this point, in which free gold as well as native silver is said to be found. From the specimens I have seen I should judge the silver occurred as usual in small stringers parallel to a large barren lode. I have no reliable information from this district.

There are several small forces at work on veins about Thunder Bay. In some veins no silver has been found, in others merely specks, but all have some mineral, usually zinc blende, and more often their value is based on the appearance of the spar or to the fact that they lie in the same belt of diorite as Silver Islet, called Macfarlane's band. Canada First, Cloud Bay, Angus Island, "17 K," belong to this class. They are working large barren spar veins in the hopes of striking a body of rich ore. The gangue of "17 K" bears the closest resemblance to Silver Islet, and, should they cut the diorite where it contains plumbago, I have no doubt they will find very rich ore.

It is useless for any company to go to work with a capital of $20,000 to $50,000 on any of these veins, but a capital of ten times that amount might pass the barren belts into a second rich zone in depth. At present the existence of such a zone is probable, but not proven. The indications are that the veins themselves have never given out, that the band of mineral continues to the greatest known depths, impoverished in silver, it is true, but still carrying a few ounces, showing that the metal is not entirely wanting. Wherever the silver has given out a corresponding change of country rock has taken place. The future of this district depends on the results of the deep explorations at Silver Islet and Duncan, and on the possible discovery of a surface deposit similar to that at Silver Islet.

Iron Ore.—There are many places on the North Shore where iron ore has been found in large quantities, especially in the western portion. The difficulty with all the deposits is the large amount of chert occurring with the ore in bands, or the ore itself is very silicious. Some of the purest specimens come from the foot of Thunder Bay. So long as the South Shore furnishes the immense quantity of pure ores as at present, it is not likely that capital will be attracted to these deposits.

Taken as a whole the history of this district has been such that capital is not attracted to it. All the mines started with the idea that they would pay from the start as Silver Islet did, and that, too, when ore must pay $150 per ton to get it into bullion, with no provision to treat anything of lower grade. Those that produced a few tons, worth perhaps $200 or $300 per ton, were disappointed, naturally, in the result when half the proceeds went into expenses away from the mine. Silver Islet was very slow to realize it, though a dressing process was recommended when the first ore was smelted, and it was not until a pinch of the vein began to frighten the manager that the matter was taken in hand. Different amalgamation processes were tried, but without success. At this point, Captain Frue, the superintendent of the Islet, perfected his vanner, which, for the character of the ore, is as perfect a machine for its simplicity as there is, and at a very small cost produces a product fit for smelting, containing 90 per cent. or more of the value of the ore. I think this machine has fulfilled all the requirements of the case. The problem was to concentrate an ore that contained only 1 to 3 per cent. of any metallic mineral, 0.2 per cent. at the most being native and sulphide of silver; the gangue being spar, quartz, and some diorite. The waste rock from the richest part of the mine assayed about 40 ounces, but as the vein became poor the stamp-rock ran down to about 10 ounces, so that the process had to be cheap. The cost has proved to be less than $2 per ton, while the concentrations assay from 500 to 1500 ounces per ton. The loss appears to be mostly in fine float minerals, also in comparatively large pieces of native silver, weighing several milligrams, that are carried over the belt with the waste. The same machines are in use at Duncan, and save 90 per cent., as careful tests have shown.

Should new enterprises be undertaken in this district, they will begin where the older companies left off, and prepare to treat the poor rock first.

List of Specimens Exhibited.

1	Chert,	Country rock,	Duncan.
2.	Dolomite,	"	"
3.	Trap,	"	"
4.	Breccia, with silver,	Contact rock,	"
5.	Pink calcite,	Gangue,	Silver Islet.
6.	Amethyst calcite,	"	Duncan.
7.	Fluorite,	"	"
8.	Black slate,	Country rock,	"
9.	Green slate,	"	"

10. Rich native silver,	Ore,	Duncan.
11. Argentiferous zinc blende,	"	"
12. Rich ore,	"	Jarvis Island.
13. "	"	Silver Islet.
14 No. 2 ore,	"	" "
15. Quartz,	Gangue,	Silver Harbor.
16. Sulphide,	Ore,	" "
17 Native silver and niccolite,	"	3 A Mine.
18 Bismuth,	"	Bismuth Mine.
19. Gold ore,	"	Jackfish Lake.
20. Lead ore,	"	Near Duluth.
21 and 22 Ore,	"	Little Pic.

THE COMMERCIAL ANALYSIS OF FURNACE GASES.

BY PROF. T. EGLESTON, PH.D., SCHOOL OF MINES, COLUMBIA COLLEGE, NEW YORK CITY.

THE importance of making analyses of gases in furnaces which are used for metallurgical purposes is every day growing more and more evident. It is the only method of understanding the reactions that take place in the furnace, and of economically conducting the operations both with regard to the fuel used and the reactions which take place on the bodies to be subjected to the influence of the heat and gases.

As a knowledge of the composition of gases is becoming every day more necessary to the proper conduct of furnace operations, it seems desirable that furnace managers should generally know that the analysis of gas for commercial purposes is neither difficult, tedious, or expensive, and that it does not necessarily imply the use of corrections requiring difficult instrumental observations and long and tedious mathematical calculations.

Any method, therefore, which will tend to render these analyses simple will also tend to having them made and repeated as frequently as the analyses of the ores and other materials charged in the furnace. They should be made even more frequently, as their composition is affected by any change in the condition of the furnace, and a knowledge of their composition will give a ready clue to the unseen and otherwise not easily detected changes which are taking place.

The only practicable method of making industrial analyses of gas is that of measuring volumes in graduated tubes. The methods by

direct weight are too long and too complicated for commercial uses. The method by volumes has the double advantage that it can be made so exact in the hands of an expert as to be suitable for ultimate analyses, or it may be made so simple as to be within the capabilities of a common workman, who may be easily taught to determine volumes to within one-half per cent., which is a sufficiently close approximation for any industrial purpose.

It may be said in general terms that the normal working of any furnace will depend upon the ratio of $\frac{CO^2}{CO}$, and that it is in keeping the ratio of these two gases in proper relations that successful management depends. For ordinary commercial operations this relation can be determined in a few minutes, and is all the more important since it is desirable to know what it is, both at the entry of the gas into the furnace, and at its exit either into flues or into the air. By determining what this normal relation should be, it is quite possible to foresee the working of blast furnaces twenty-four hours ahead, and thus provide against accidents, and sometimes to bring down the consumption of fuel, and extend the length of a campaign very greatly. Accidents in blast furnaces will generally show themselves in their first stages in the composition of the gas at least twenty-four hours before they manifest themselves at the tuyeres or in the slag. An examination of the gas will, therefore, give a ready means of preventing them.

It is not usually sufficient for this, however, to make single analyses at intervals; it is necessary that they should be repeatedly made, and that, as a general rule, the taking of the sample of the gas should be continued over several hours.

While in some industrial gases the hydrocarbons, sulphurous acid, and occasionally chlorine are to be determined, for ordinary metallurgical purposes, the determination of carbonic acid, carbonic oxide, oxygen, and nitrogen (which will be the residue), only is necessary, since these are the gases which are principally affected by the process. As a general thing the hydrocarbons, except in generators, are not found in any considerable quantity; nor is oxygen, except in furnaces where its presence is certain beforehand on account of its introduction in large quantities with air. To perform such an analysis in the works for commercial purposes the modified Orsat apparatus is the one which it is advisable to use.

Since the description of the Orsat apparatus was published in Vol. II of the *Transactions of the Institute*, a large number of furnace managers have introduced it into their works, and are daily making

use of it to control the working of their furnaces. The constant demand made for it in Europe and in this country has led to important modifications; and the importance of having a simple apparatus which can be put into the hands of workmen has brought about several changes which tend to make it more portable and more complete.

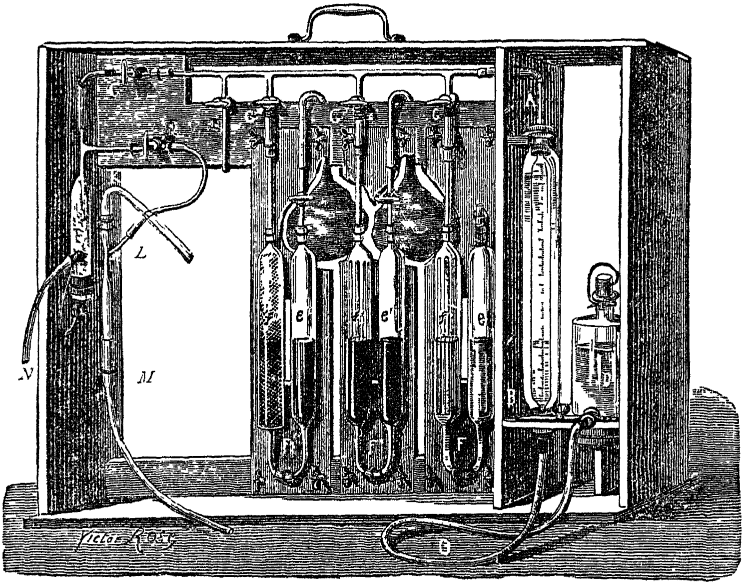
The Orsat apparatus as now modified does not differ in principle from that described in Vol. II of the *Transactions*. There has been added to it an appendage for the determination of hydrocarbons, which makes the apparatus more complete and useful in cases where mine gases are to be analyzed for the detection of fire-damp or for the examination of producer gases or any other gas. The shape of the apparatus, however, is somewhat different, the jars and bell glasses being replaced by U tubes. The volume of absorbent liquid used is also smaller, and the apparatus can consequently not be used so long without changing the liquid. This is, however, not a practical difficulty, as the number of analyses, as was shown in *Transactions*, Vol. II, page 234, can be almost indefinite.

This apparatus as now modified is shown in Fig. 1. It consists of a measuring-tube, A B, which is surrounded by water in order to have the gas at a constant temperature, and thus avoid the necessity of thermometers. The measuring-tube is open at both ends, and is fitted into the cooling tube by means of india-rubber corks. The bottom of the measurer is connected by means of a rubber tube with a small bottle, D, having an opening at the bottom, which contains acidulated water, and which is to serve both as an aspirator and expulsor of gas. The other end is connected with a small tube, which is not over a millimeter in diameter, which goes to the left of the measuring-tube. It has four arms, G, G′, G″, and I, each of which is provided with a glass stopcock. The prolongation of the tube itself is also provided with one at *C*. The one at the end connects with a tube, P, which is filled with cotton in order to filter smoke or dust from the gas which is drawn into the instrument through the rubber pipe, *N*. This filter connects by a glass tube at right angles, having a stopcock, R, with a trompe, L M, which is used both for aspiration and for clearing the apparatus of gas by connecting it with a water-bottle by the tube, K.

Each one of the U tubes is fitted to a wooden upright to which it is raised. The whole is then secured to the frame by thumbscrews, so that it can be easily removed to refill the tubes or alter the solutions.

A German modification of the apparatus has the tubes with the stopcocks made of pewter. This is a very objectionable form of it, as it is much more likely to become foul.

FIG. 1.



In order to be sure that the samples of gas taken for analyses represent the mean composition of the gases, they should be taken through a pipe with a long slot, and the gas collected should be passed through a Liebig condenser before it is used, so that it may be quite cool before it is introduced into the apparatus. The three stopcocks nearest the measurer connect with the U tubes, the first one of which, $e\,f$, contains potash; the second, $e'\,f'$, pyrogallate of potash; and the third, $e''\,f''$, an ammoniacal solution of chloride of copper. The first is destined for the absorption of carbonic acid, the second for the absorption of oxygen, and the third for the carbonic oxide. These last gases may be determined together as described in Vol. II. When only the gases of a blast furnace are to be analyzed, two tubes are all that are necessary, but as the extra tube does not increase the difficulty of manipulation and the extra cost is very slight, it is generally best to have three, as then the apparatus can be used in many cases where it would not be convenient to use two.

A considerable difficulty has been found in the use of the ammoniacal solution, it having been found to absorb very slowly. This

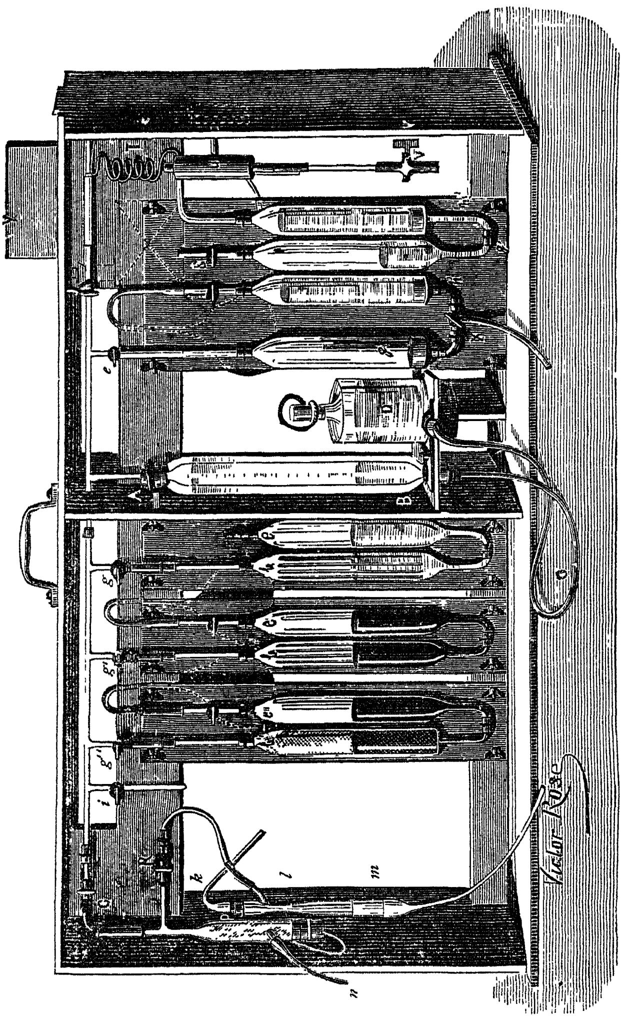
solution, in order to have the greater surface, is formed by placing a roll of copper-wire gauze in the tubes. In order to get the requisite amount of surface it has been found desirable, with some gases, to replace this copper-wire by copper disks with short pieces of glass tubing between them. The slowness with which this solution works is caused, however, by the fact that the salt which produces the absorption is not always present. The ammoniacal solution of chloride of copper absorbs oxygen very rapidly and forms an oxychloride of copper. When the oxychloride is formed the solution is blue, and when it is in this condition it absorbs the carbonic oxide rapidly; but after a number of passages, the solution works very slowly and becomes green. In this case the oxychloride of copper, which is the absorbent, has been entirely used up, and it is necessary to make the solution blue again by the absorption of oxygen from the air, when it will absorb again as rapidly as at first.

As the pyrogallate and oxychloride solutions are very sensitive, the ends of the U tubes, $e' f'$ and $e'' f''$, instead of being freely opened to the air are connected with rubber bags, the object of which is to prevent the access of the atmosphere. The oxygen of the air contained in the bags becomes rapidly absorbed, and the gas between the top of the solution and the interior of the bag in a short time will be composed of nothing but nitrogen. The details for using the left side of the apparatus are fully described in the article in Vol. II. In the complete apparatus, Fig. 2, the gallery is continued to the right, having a stopcock, J, on the gallery itself, and one projecting tube, E, with a stopcock. The end of the gallery is attached to a spiral platinum tube, T (which is to be heated by an alcohol lamp, or by a Bunsen gas-burner placed below it), which connects with a stopcock, V, below it, by which the supply of gas is regulated. The apparatus is arranged for one or the other or both means of heating the platinum tube. There are connected with this gallery two U tubes, one of which, $g' h'$, serves as a reservoir, and the other, $g h$, is used for the production of hydrogen, which, with a large excess of air, is used to burn the hydrocarbons. There will be no danger, however, of an explosion, on account of the great excess of nitrogen and the capillarity of the tube. To insure complete combustion, the gas is mixed with a mixture of hydrogen and air.

The gas having been passed through the left side of the apparatus, is transferred from the measurer to the capillary tube, and from there into the U tube, $g' h'$ (partially filled with water), which serves as a reservoir for the gas. The other U tube, $g h$, which serves for

the production of hydrogen, is cut off from the gallery by a stopcock, E, while the transfer is made. It contains zinc and sulphuric acid, which, formed under pressure, throws the liquid back into the opposite side, thus forming a reservoir of hydrogen, and preventing

FIG. 2.



the attack of the zinc except when it is necessary. In order to prevent the waste of zinc while the apparatus is not in use, the acid is cut off by the stopcock, X, which also serves to empty both tubes when it is necessary.

When the hydrocarbons are to be determined, 200 divisions of the gas are taken, and all the gases that can be determined on the left side are separated first; 40 to 50 divisions are then taken for analysis, and all the remainder of the gas turned into the pyrogallate solution, *f′ e′*. Ten to fifteen divisions of hydrogen, and 130 to 150 of ordinary air, taken through the tube, N, are then introduced, the quantities being determined by the supposed amount of hydrocarbons present. The lamp, U, is lighted, and the mixture made to pass very slowly three or four times back and forth through the platinum spiral, T. Great care must be used not to introduce moisture into the platinum tube for fear of an explosion, which would break the glass tubes. The gas is then passed into the measurer, A B, and cooled, and the contraction read. In the burned gas carbonic acid and oxygen are determined. If there is no oxygen the combustion has not been complete, as there has not been sufficient air, and fresh air and hydrogen may be added, or, better, the analysis may be commenced over again by using the reserve in the pyrogallate tube. Complete combustion thus transforms the carbon into carbonic acid, and the hydrogen into water.

The carbonic acid is determined directly by its absorption in the potash tube, *e f*. The amount of water produced must be calculated; this is very easily done, for the quantity of air introduced is known, and if the number of divisions of it is represented by m, we have .021 m of oxygen, and .079 m of nitrogen; the nitrogen is unaffected and remains behind, while the .021 m of oxygen has been used to burn the hydrogen introduced into the U tube, and both the hydrogen and carbon of the hydrocarbon. Some of it has not been used, as the air must be in excess in order to be sure that the combustion has been complete.

Of these four quantities, three are known. Oxygen in excess has been determined in the pyrogallate solution. The quantity of hydrogen introduced is known. It has required for its combustion one-half its volume of oxygen. The carbon of the hydrocarbons has been transformed into carbonic oxide, to do which has required a volume of oxygen equal to its own. These volumes all being known, the quantity of oxygen used to burn the hydrogen of the hydrocarbons is consequently known by difference. This quantity of oxygen has produced double its volume of water, and, consequently, all the elements for making the calculation of the hydrocarbons are known.

The total volume of the hydrocarbons can also be determined, for

after all the determinations have been made, the measuring-tube contains only nitrogen. This nitrogen is the sum of that contained in the gas and of that introduced with the air used to burn the carbon and hydrogen. The nitrogen contained in the gas was determined before the gas passed the platinum spiral. The nitrogen in the air is known from the quantity of air introduced. Hence all the elements are determined.

This method is sufficiently exact for all commercial purposes; the only inconvenience that it has is from the fact that as the oxygen to burn the carbon and hydrogen is all derived from the air, a quantity equal to fifteen times the total amount of the hydrocarbons to be analyzed must be introduced, besides which another amount must also be added sufficient to burn the hydrogen. This method is for commercial purposes much preferable, however, to using oxygen, as pure oxygen cannot always be had, and it would generally be impracticable to have it on hand for industrial operations; besides which, the method is only a commercial one. Its errors, however, may be made to be not over one-half per cent. These errors are caused by the fact that the hydrocarbons are slightly soluble in the copper solution, and that acetylene, which some of these gases contain, precipitates the copper as an acetylide of copper. It is therefore not well adapted to complete analyses of hydrocarbons, or for the analysis of illuminating gas, but sufficiently exact to determine the presence of hydrogen and hydrocarbons in furnace gases or in fire-damp in mines, or for any ordinary commercial purpose. The very slight error is not sufficient to make any material change in determining the caloric powers of the different substances examined.

THE POSITION OF THE AMERICAN NEW RED SANDSTONE.

BY PROF. PERSIFOR FRAZER, JR., PHILADELPHIA.

COMPARATIVE columns expressing the series of rocks of the lower half of the Mesozoic age in this country and in Europe are not yet definitely established. The following represents a co-ordination of the beds in England and Germany,* with a list of materials to be worked in from this country.†

* Cotta, "Geologie der Gegenwart."

† Section from York to Dillsburg. Report C, 1875; Second Geological Survey of Pennsylvania.

	ENGLAND.	GERMANY.	NORTH AMERICA.
JURASSIC.	Inferior oolite. Lias.	Black Jura Bituminous coal and Limestone. Sandstone underneath.	
TRIASSIC.	Upper Marl.	Keuper. (Sandstone, marl, and gypsum.)	Upper calcareous conglomerate. Red and green micaceous sandstones.
	Sandstone.	Lettenkohle with sandstone and clay slate.	Iron ores (cupriferous). Green and gray sandstones.
	Lower Marl.		Clay. Bluish sandstone.
	Newent Sandstone.	Upper Muschelkalk.	Red sandstone. Iron ore.
	Hatfield Conglomerate.	Gypsum, Anhydrite, and Rock salt. Lower Muschelkalk, Röth. (Ripple limestone.) Gypsum and Rock salt. Variegated sandstone.	Red sandstone. Shales and red clay. Green slates. Gray and green sandstone Blue mud rock. Coarse red sandstone with quartz pebbles.
PERMIAN.	Magnesian Limestone and Marl Slate.	Upper Zechstein. (Stink stone, Dolomite, Gypsum, and Rock-salt.)	Coal and coal shales (?). Lower cupriferous horizon.
	Marl Slate.		Greenish-yellow shales. Red shale finely laminated.
		Lower Zechstein and Kupferschiefer.	Red shale. Red sandstone.
	Lower New Red Sandstone.	Upper Rothliegendes. (Conglomerate and Sandstone) Lower Rothliegendes. (Sandstone. Clay slate and argillites.)	Green shale. Red argillaceous sandstone. Shales. Massive gray sandstone. Red sandstone between shales. Red shales. Brownish-gray shales. Lower calcareous conglomerate.

NOTE.—It must be understood that the right hand or American column is not arranged in any parallelism with the other two, but it is simply a rough list of varieties of rock encountered from N. W. to S. E. across the broadest expanse of Mesozoic in Adams County, Pennsylvania.

In regard to the divisions of these Mesozoic strata, H. D. Rogers selects as a typical specimen the portion of General Section No. II, from near Attleboro' to the mouth of Durham Creek, as presenting the widest range and most numerous varieties of material.

The lowermost (southernmost) stratum, with a breadth of 3.2 kilometers or two miles, he designates as coarse reddish-gray quartz, with occasional layers of conglomerate sandstone. This is exposed below Yardleyville. The materials out of which these layers are built up are chiefly quartz and feldspar, with hornblende and a small amount of mica, while much yellow hydrated peroxide of iron is distributed in nests.

Above this belt is a zone, also about 3.2 km. in width, of which the predominant rock is a coarse-grained, pinkish sandstone, composed of transparent quartzose sand, white specks of kaolinizing feldspar, and occasional flat pebbles or flakes of the compact red shale or argillaceous red sandstones. From this belt comes the best building material of the whole formation.

The next overlying mass is much broader, 9.6 km. (about six miles), and extends from the last-named to the vicinity of New Hope, beyond the anticlinal of auroral limestone which comes in there. This extensive mass "includes all the more common varieties of the red shale and the red or brown argillaceous sandstone."

Upon this lies a group of about 1.6 km., or one mile, in breadth, much more diversified, and consisting of red sandstones and coarse yellowish conglomerates subdivided by thinner beds of soft red shale. "These coarse rocks much resemble those of the first-described division at the base of the formation." Upon this lies a belt of nearly fourteen miles, or 22.53 km., in extent, consisting of the "usual alternation of red shales and soft argillaceous red sandstone."

Assuming the average dip given by Prof. Rogers as 18° to 20°, and the breadth of the line of this section as 48.28 km., or 30 miles, and also the monoclinal nature of these strata, we have the enormous perpendicular thickness of 15.7 km., or 9.75 miles, or 51,500 feet of lower Mesozoic rocks, presented here—a thickness equal to about one-half of all formations taken together, with the exception of the unknown lowest: or more than 11,000 feet thicker than the whole of the strata in the State of Pennsylvania (as estimated by Dana), exclusive of the Triassic, which, as this author remarks, "may add a few thousand more."

The first thing which strikes one in comparing the foreign and American tables of strata is that the distinguishing features of the former are wanting in the corresponding horizons of the latter, and either that the difference of constitution of the two formations must be very great or that the analogous events of their history are uncontemporaneous.

The bituminous coal and limestone of the lower Jura of Germany, and indeed the Lias of England, are totally wanting in the Atlantic district (to judge by lithological description), and there appears to be but little parallelism between the other members of the Triassic in the two countries.

Fossils from Phœnixville and Gwynedd, Pa., have been identified as Triassic (see Dana), the former in black slates; but a line through these localities, if continued southwest and parallel to the northwest border of the Mesozoic strata between the Schuylkill and the Susquehanna, will be found to lie altogether outside of its present area, and only to re-enter that area two or three miles east by north of Weigelstown.

If we might assume the tolerable constancy of horizon maintained by the present northwestern edge of the Mesozoic in Pennsylvania (which would be a hazardous assumption), the cupriferous slates near Phœnixville would not fall far from the line of those near Bonnaughton.

The black calcareous slates of Phœnixville would, in this view, not connect with the coal-bearing belt which was noticed in Report C, for 1874, *Second Geological Survey of Pennsylvania,* in the catalogue of specimens, but would underlie it, if the apparent dip may be trusted.

This coal seam, of only a few centimeters or inches, seems to belong to the series which form the Conewago Hills, but so far as I know it is not even coextensive with this short range. From its direction and place, if continuous, it would pass not far from Gettysburg and near the middle of the Mesozoic belt.

Mr. Isaac Lea, in his Monograph on a Fossil Saurian of the New Red Sandstone of Pennsylvania, (1852), says: "In the collection of the Academy" (of Natural Sciences, of Philadelphia) "we have a collection from Bristol, England, some of the specimens of which are so similar in their brecciated form and in their colors to some specimens I procured near Reading, as to defy a separation of the specimens if placed together; but the much more important characters consist in the similarity of the structure of the bones, together with the single small gasteropod found in the brecciated limestone rocks of both continents." From what dim light we have it would seem at least possible that the base conglomerate of the series would find its analogue in the magnesian limestone of England, and the Zechstein of Germany;* though few

* Second Geological Survey of Pennsylvania, District of York and Adams.

fossils have been found to corroborate this hypothesis, and there must necessarily be striking differences of lithological constitution between a formation laid down in its regular order in the column and one under which the whole of the Permian, Carboniferous, and Devonian series are wanting.

If we might assume such a thing, then the variegated sandstone of Germany being the next following belt (the base of the Trias), would correspond to a certain degree in outward appearance with the various shades of red and pink sandrocks which rest upon this conglomerate; but the saliferous beds and Muschelkalk which are characteristic and distinctive fail entirely, and seem to show that, if there be any analogy between the two, it does not amount to identity of origin.

It is otherwise with the English Trias, which also begins with the Conglomerate, on which rest sandstones and marls up to the lower limit of the Jura. If the marls be replaced by shales and enriched by the presence of copper and micaceous iron ores, and the absence of saliferous strata here be passed over, it would not be impossible to conjecture that our entire series represents the upper half of the Triassic of Europe, the conglomerate at its top being the analogue of those beds below the nether oolite limestone.

But the thickness here stands in the way of this hypothesis. How are we to conceive that the same formation in the two continents should be so different in extent that one should represent in its entire thickness but a very few thousand feet, while the contemporaneous deposit of merely its upper portion should reach 51,000 feet?

It is true that this latter enormous thickness, while it cannot be just at present corrected, and seems to follow from the observations made by H. D. Rogers,* and confirmed by those of many others, in-

* Rogers is explicit in the statement of his belief in the actual shallowness of the Mesozoic red sandstone, as the following excerpt from vol. ii, part ii, p. 814, of his Final Report on the Geology of Pennsylvania, will show. After expounding his views as to the probability of the original deposition of strata in inclined layers by curling waves, and by matter held in suspension without waves, and of the danger of overestimating the thickness of strata from this cause as exemplified in the current views of the thickness of the Carboniferous of Wales and of Nova Scotia, he employs the following language: "Perhaps the most remarkable example of original obliquity of deposition on an extended scale to be met with anywhere is that which is presented by the Mesozoic red sandstone of the Atlantic slope of the Middle States. This formation exhibits in New Jersey and Pennsylvania a width in many places of more than 25 miles, yet it displays but one direction of dip, or even one series of original planes of sedimentation throughout the entire space. The slope of the beds is everywhere north, and at

cluding myself, is of itself in the nature of a *reductio ad absurdum* to the hypothesis of the uniform bedding and monoclinal structure of this formation.

But after the diamond drill shall have settled the depth of the formation in Pennsylvania, the latter will still be found too great to be crowded into the half of the Triassic period.

If too much attention be not wasted on the minute details of resemblance, which can hardly be expected in rocks laid down so hastily over wide areas, we may expect to find one or two points at which to attach these two series together.

One is the lower horizon of cupriferous slates. These may be compared with the German Kupferschiefer.* Under it the "Lower New Red" of Sedgwick would take its place as the lower sandrock, while beneath this in Germany is found the Conglomerate. Above this occurs a considerable thickness of measures, in which, as yet, no fossil remains appear, the first of the latter being, as above stated, clearly identified as Triassic. Other rocks take the place of the salt, gypsum, etc., bearing beds, while the Lettenkohle or argillaceous coal-seams may correspond in horizon to the carboniferous strata observable at many points in the basin, and the upper marl and Keuper are well represented by the green marls which crown this Mesozoic series at its upper (?) northwest level, lying against the South Mountain rocks in the vicinity of Dillsburg. By this hypothesis, then, the "New Red" of York and Adams Counties would reach from the middle portion of the lower half of the Dyas or Permian at least to the base of the Lias, including all the rocks attributed to the Trias and the transition beds below it, except the lower Rothliegendes of the German scale. That such an hypothesis should be temporarily adopted with great caution admits of no doubt, for

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angles varying from 10° to 30°. *Now, if computed trigonometrically, this formation should possess a depth of many miles; yet there is the amplest evidence in the physical geography of the region, and above all in the exposure by denudation of the floor upon which it rests, that it is extremely shallow.* In the neighborhood of New Hope, some 13 miles from its south margin, where the formation should have by the usual rule of estimation a depth of not less than 10,000 or 12,000 feet, its bottom is actually exposed and the thickness is not more than fifty feet. It was deposited in truth in a wide, shallow estuary or tidal bay, ascending southwest into a broad, shallow river, but its materials were swept in from the south and southeast, *across* its channel, which evidently lay next its northwest shore, and were slantingly laid down, the whole process assisted by gradual lifting out from beneath its water of its southeast coast, accompanied by a rising of the land in that direction."

* See Bakewell, New Haven, 1839.

the evidence to sustain it is indirect and somewhat doubtful, yet, nevertheless, this hypothesis tallies better with known facts than any other known to the author, in spite of the many serious objections which can be raised to it.

Until quite recently but little was known of the fossils of this period in the West, and the absence of salt and of distinct marine fauna in the East led geologists to ascribe to this portion of the New Red a fluviatile or at most brackish origin. Spirifers, Orthoceras, and Goniatites have been found in Nevada and California, besides Lamellibranchs and Ammonites (genus Ceratites).

Emmons's *Dromatherium sylvestre*, the only mammal yet discovered in these beds, and the other vertebrates (fishes, saurians, and birds), do not serve to distinguish this formation from the Permian by any sudden elevation of types. The marine fossils are allied to those of the Permian, and even of the Devonian (Goniatites). In fine, there is no palæontological evidence on which to separate the lower of the New Red series from the Permian or the upper from the Jurassic.

One of the characteristic features of these singular beds is their red color, a feature sufficiently illustrative of their popular names, "New Red" (as a whole) and Buntsandstein, as a part. Various ingenious theories have been conceived for the purpose of explaining this color, possessing more or less plausibility. All must agree, however, that the immediate cause of the color is the presence in these rocks of a large quantity of oxide of iron, more or less hydrated. Where all the iron came from which must have been employed in the coloring of such enormous masses of rock all over the globe, need not concern us here. Some have supposed the origin to be cosmical, *i. e.*, that a huge meteor or several millions of small ones entered the earth's atmosphere, were burnt, and rained down as red dust upon those seas.

It is much more to the point to inquire how much iron exists in a given volume of these rocks, for the answer to the question may be shown to have an important bearing on the theory of the genesis of the Triassic iron ores.

It has often been remarked (and requires no substantiation here) that all the beds of the New Red are not red. On the contrary, perhaps one-half of the whole series presents to the eye that lead-gray and drab color which is typical of rocks long leached by the rain and thus deprived of their iron. The rest (chiefly sandstones) exhibit, as before stated, all tints of red, from the sombre brown-red, so familiar to the eye in New York and Philadelphia, in the fronts

of many private dwellings, to the sandstone tinged lightly with pink, and from this cause reminding one more of the Tertiary sandstones. A fair specimen (No. 1304, catalogue report of 1875) of the variety most common was reduced to powder, and this, after being thoroughly mixed together, was examined.

The specific gravity of the rock was found to be 2.615.

	Gram.
Of metallic iron one gram contains	0 0·27593
Of iron sesquioxide one gram contains	0.04
One c.c of the rock weighs	2.615
One c.c. of the rock contains sesquioxide of iron . . .	0.1046

Every meter cube of the rock contains of sesquioxide of iron 104.6 kilos. Hence for every kilometer on the strike, 20 meters on the dip, and 1 metre in thickness, there are contained 2,092,000 kilos., equal to 2092 metric tons.* It is evident that, if such an amount of iron were concentrated by erosion and washing, all the iron mines which occur within the borders of the New Red could be ascribed to this cause. Of course this does not prove that such is the source of these mines; nevertheless it is a point worth considering.

A far more difficult matter is to determine with reasonable probability where such a mass of iron came from, and what part it has played in the history of the deposits with which it is associated.

The New Red Sandstone of Eastern America does not usually occupy its proper place above the Carboniferous and Permian strata. It lies in a belt which crosses the edges of much older strata than those which precede it in the normal series; seldom, if ever, exhibiting underneath its beds any members of formation higher than the middle Silurian, while much of its foundation is composed of Huronian and other Archæan rocks. Part of these latter are rich in iron, and may be safely viewed as the sources of the metal in the Mesozoic series. Part of them are destitute of iron, but as yet no absence of iron from the immediately overlying New Red has been made out.

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* To give this percentage of iron in American standard units, there are contained in every mile of strike, one chain of dip, and one yard of thickness, 6193.44 long tons of sesquioxide of iron.

THE HOLLENBACK SHAFT, LEHIGH AND WILKES-BARRE COAL COMPANY, LUZERNE COUNTY, PA.

BY JOHN HENRY HARDEN, UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA.

THIS shaft, located in the northern anthracite coal-field about 2300 feet southwest from the court-house at Wilkes-Barre, in the County of Luzerne, Pa., is the property of the Lehigh & Wilkes-Barre Coal Company. The sinking and cribbing to the solid rock (see isometrical view on Plate IX) was conducted by Mr. W. W. Kenrick.

Dimensions of the earthwork to the foundation of the cribbing, 51′ 2″ long, 17′ 4″ wide, 31′ deep. Total amount of excavation in cubic yards, 998.5. Dimensions within the permanent cribbing, 45′ 4″ long, 11′ 16″ wide, 31′ deep, divided into six parts by buttons 8″ x 12″, each division, 7′ x 11′ 6″. Permanent cribbing 12″ x 12″; temporary cribbing 8″ x 10″; backing, 3″ thick; clay puddle to exclude surface water, 12″ thick; conductors, 8″ x 5″; lining, 1″ thick from top to bottom of the shaft.

In the latter part of the year 1871, Mr. H. Murray & Son contracted with the company for the continuation of the work at the rate of four hundred dollars per yard in depth, to a point 100 feet below the Hillman seam of coal; for the succeeding 100 feet the price to be increased twenty-five dollars per yard, and so on until the bottom rock of the Baltimore seam of coal was found. The size of the shaft within the cribbing timbers is 45 feet 4 inches by 11 feet 6 inches, having six divisions of equal dimensions, 7 feet by 11 feet 6 inches, giving room for what is known as the "standard diamond" car, whose capacity when level full is 100 cubic feet, but when loaded by the miner 4 inches above the top contains 112 cubic feet.* Two divisions of this shaft are intended for hoisting coal from the Hillman seam, two from the Baltimore seam, one for ventilation, and one for pumps.

The works were planned for two pairs of direct-acting, high-pressure engines, twenty-four boilers, and for an estimated output of 2500 tons of coal per day from the two seams.

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* Size of the "standard diamond" car, 8′ 10″ x 4′ 3″ x 2′ 8″ = 100.1.4; loaded 4 inches above the top, 8′ 10″ x 4′ 3″ x 3′ 0″ = 112.7.6.

The measures dip to the northwest about 18°. The sinking was carried out under favorable circumstances, the water being handled with small steam-pumps and buckets to the depth required, about 600 feet. Calculating eight inches at the ends, and six inches at the sides for the shaft lining, the quantity of rock sinking in each yard in depth is sixty-four and three-quarters cubic yards, making the cost per yard six dollars and seventeen cents, the increased price for the lower portion amounting to thirty-nine cents per yard, the company finding all headgear, engines, pumps, ropes, etc.

This is one of the largest shafts, though not the deepest, in the anthracite regions, and probably larger in area than any other shaft in the world. Begun when the coal trade was good, a demand was expected for all the coal that could be mined. To-day the company do not need this so-called improvement, but would gladly see the money it and other work of like character have cost.

The shaft when set going will develop an immense body of coal from the Hillman, Baltimore, and Red Ash, they being the three seams upon which a certain value can be set. There are others, but of inferior quality and thickness. Like the Diamond shaft, belonging to the same company, this will have a "blind side" on its northeast strike, a disadvantage under any circumstances wherein a large output of coal is desired, as will be obvious to any one studying the question. Unlike the Diamond shaft, it has a large area of coal "above bottom." It is separated from the Diamond Basin by a natural barrier, or anticlinal, and requires independent drainage facilities. Upon the summit of the anticlinal a new shaft intended for a second opening has been commenced to comply with the law of Pennsylvania requiring every mine to have two outlets. Two shafts of moderate size would have rendered this unnecessary.

CHART SHOWING THE PRODUCTION OF ANTHRACITE COAL IN THE LEHIGH, SCHUYLKILL, AND WYOMING REGIONS; ANTHRACITE, BITUMINOUS, AND CHARCOAL PIG IRON IN THE UNITED STATES, AND PETROLEUM IN PENNSYLVANIA, FROM 1820 *TO* 1876.

BY JOHN HENRY HARDEN, UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA.

It appears that in the earlier days of anthracite coal mining, 1824–25, the Lehigh region mined 76 per cent. of all the coal sent to market. During the same period Wyoming sent 12 and 5 per cent. respectively, whilst the Schuylkill sent 11 and 18 per cent., the number of tons marketed being in those days very small indeed.

In the year 1828 the Schuylkill region mined over one-half of all the coal sent to market, and continued to do so for thirty years (with the exception of the year 1831), until 1858; since that date the production has declined very steadily in comparison with the other regions, until, in 1876, it was only 34 per cent.

Wyoming, in the year 1820, was mining 40 per cent., but the production of all the regions was very small; in six years it declined to 5 per cent., increased to 34 per cent. in 1831, declined to 10 per cent. in 1838. Since which time the increase has been gradual, until 1873–75 Wyoming produced over 50 per cent. of all the anthracite coal sent to market. In 1867 the production exceeded that of Schuylkill, and has continued to do so since that time.

In the year 1876, during the existence of the "coal combination," Wyoming lost 9 per cent.; during the same time Lehigh gained 7 and Schuylkill 2 per cent. over their relative production of the preceding year, the decrease of Wyoming being two and a half million tons, the increase of the Lehigh one million, the decrease of the Schuylkill nearly three-quarters of a million.

The extraordinary production of the Lehigh region at a time of decreased demand and in opposition to an agreement with the other regions to limit the supply to the supposed demand was the cause of the disagreement which ultimately broke up the combination of the great coal-producing and carrying companies.

The Lehigh region produced very steadily, from 1829 to 1854, an average of about 22 per cent. of the whole production. From 1854

to 1875 the average has been about 18 per cent., showing very plainly that the production of the Lehigh has not kept pace with Schuylkill or Wyoming.

COMPARATIVE PRODUCTION OF ANTHRACITE IN WYOMING, LEHIGH, AND SCHUYLKILL REGIONS, FROM 1820 TO 1876.

Years.	Wyoming. Per cent.	Lehigh. Per cent.	Schuylkill. Per cent.	Years.	Wyoming Per cent.	Lehigh. Per cent.	Schuylkill. Per cent.
1820 . . .	40	34	25	1849 . . .	23	24	52
1821 . . .	30	45	24	1850 . . .	25	21	53
1822 . . .	24	55	20	1851 . . .	26	21	52
1823 . . .	14	72	13	1852 . . .	26	22	51
1824 . . .	12	76	11	1853 . . .	29	20	50
1825 . . .	5	76	18	1854 . . .	27	20	52
1826 . . .	5	59	35	1855 . . .	27	18	54
1827 . . .	5	48	46	1856 . . .	28	19	52
1828 . . .	6	36	57	1857 . . .	29	19	51
1829 . . .	12	22	65	1858 . . .	32	20	47
1830 . . .	27	22	50	1859 . . .	34	21	44
1831 . . .	34	20	45	1860 . . .	34	21	44
1832 . . .	27	18	54	1861 . . .	38	21	40
1833 . . .	27	22	50	1862 . . .	39	17	43
1834 . . .	11	28	60	1863 . . .	39	20	40
1835 . . .	16	23	60	1864 . . .	39	20	40
1836 . . .	15	21	63	1865 . . .	34	19	46
1837 . . .	13	25	61	1866 . . .	38	17	44
1838 . . .	10	29	60	1867 . . .	42	16	41
1839 . . .	15	27	57	1868 . . .	43	18	38
1840 . . .	17	27	55	1869 . . .	44	14	41
1841 . . .	20	15	64	1870 . . .	49	19	31
1842 . . .	23	25	51	1871 . . .	44	14	41
1843 . . .	23	21	55	1872 . . .	48	19	32
1844 . . .	23	23	53	1873 . . .	51	16	32
1845 . . .	23	21	55	1874 . . .	47	19	33
1846 . . .	23	22	54	1875 . . .	53	14	32
1847 . . .	20	22	57	1876 . . .	44	21	34
1848 . . .	22	22	55				

To the graphic representation of the coal production I have added on the chart-lines showing the production of pig iron and petroleum from reliable data. (See Chart, Plate X.)

SHAFT SINKING AND SALT MINING AT GODERICH, HURON COUNTY, ONTARIO, CANADA.

BY JOHN HENRY HARDEN, UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA.

IN 1874, with Mr. H. Y. Attrill, of Baltimore, Md., I made an examination of some property at Goderich with reference to sinking for and mining salt. With this end in view we visited all the wells in the neighborhood, but the information sought being of so unreliable a character I advised the putting down of a borehole on the property. This has since been done, the result of which has lately been published by Dr. T. Sterry Hunt in the Toronto *Globe*. From this there appears to have been passed through six beds of salt of an aggregate thickness of 126 feet.

Rock-salt was known to exist, for, by the boring of existing wells, small crystals had been brought to the surface in the dirt, but no attempt had before been made to obtain a reliable sample or to prove the number and thickness of the beds. The question now remaining for discussion is, shall the present method of obtaining the salt be continued, or shall the beds be won by a shaft in a regular mining fashion, by which means the salt may be gotten in a condition almost ready for the market?

The present mode of obtaining salt is by boreholes from 6 inches to 8 inches in diameter drilled to the beds, into which is inserted a pump. The "feeders" of fresh water intersected in drilling the well are allowed to descend on the outside of the pump-tube to the salt beds and there become saturated, when, on use of the pump, brine is obtained for evaporation. In the beginning brine can only be had in limited quantity, but by the daily application of the pump, and the gradual solution of the salt, a larger surface becomes exposed to the action of the fresh water, and a continuous supply of brine is obtained. It will then be understood that the supply of brine is dependent upon the feeders of fresh water intersected in boring the well, which, we are told, have never shown any sign of diminution, and this is the water that must be encountered in sinking a shaft.

There are ten wells in operation at Goderich, the most important one to the present project being known as the Hawley Well, located at an elevation a few feet above Lake Huron at the mouth of the river Maitland, at a much lower level and nearer to the proposed shaft than any other well in the district. At this well the feeders

of fresh water intersected by the boring overflow at the surface from the space unoccupied by the pump, the area of which may be said to be eleven square inches, and the overflow about 300 gallons per minute, which under no circumstances has been known to decrease in quantity. It is in equilibrium at an elevation 36 feet above its present outlet. From observations made at the several wells there is no doubt that they are all connected with the same source of supply. The depth necessary for the working barrel of the pump is that due to the elevation of the mouth of the well above the level of the fresh water, to which must be added the difference of level of the salt water within the pump as being of a greater specific gravity. The suction-pipe (tail-pipe) is made of sufficient length to penetrate the beds as the only means of dividing the salt from the fresh water. The foregoing, together with a knowledge of the fact that the lowest feeder, said to be given off at the depth of 360 feet, yields a pressure of 150 pounds on the square inch, gives not an incorrect idea of the labor to be encountered.

The location of a shaft, keeping in view the solution of the beds by the present wells, requires some study, from the fact that large cavities have been formed in the beds which are now reservoirs, having direct communication through the borehole with the feeders already spoken of as being in the strata above.

These cavities, it is hardly necessary for me to say, must be avoided as fatal to the enterprise. An approximate estimate of the cubical capacity of them may be roughly estimated, but of their form and superficial extent we can know but little; yet no one anticipates that any of the present operations will interfere with the projected shaft. Still, the time may not be far distant when a solution of this question may be desired in another location.

An examination of the map of the Province of Ontario shows Goderich as occupying one of the most favorable positions for the distribution of any product to be obtained in mining. The quantity of salt shipped during last year to the American market is given as 11,375 tons, at the same time there were shipped to the Canadian market 5965 tons, making a total of 17,340 tons.

About 600 feet distant from Lake Huron, and 40 feet above its level, on the north side of the river Maitland, within the harbor of Goderich, is a most desirable position for the location of the proposed shaft. From there the product can be shipped direct from the mine into vessels trading to any of the lake ports of Canada or the United

States. The construction of a bridge over the river Maitland would make a connection with the Grand Trunk Railroad and all its connections.

For sinking the shaft one of two methods may be adopted. These I will call the English system and the Chaudron system. By the former the sinking through strata bearing heavy feeders of water is performed in the ordinary manner of dry sinking, pumping the water to maintain the bottom of the shaft in a sufficiently dry state for men to work until the feeders are all passed, and impervious measures found, upon which to rest the lining. This may be of two kinds: for feeders of high pressure, brickwork will answer all purposes, but for heavy pressures metal tubbing must be resorted to.

The former is built upon an oak curb of sufficient strength to carry brickwork of nine or fourteen inches thickness, as the case may be, filled in with puddled soil. This is commonly called brick coffering, and is built with the best material, the brick being made to suit the form of the shaft. Work of this kind has been used with success in excluding water from shafts under considerable pressure. The latter, necessary, as before said, to sustain heavier pressures, is built upon a metal curb in line with the earlier work. Upon this the tubbing is erected in segments. Between every joint is laid (with the grain towards the centre of the shaft) sheet pine lumber, about $\frac{3}{8}$ of an inch thick and the width of the flange of the tubbing, each tier or course breaking joint with the preceding one until the casing of the shaft is complete to the last course or matching pieces, when it is not unlikely special castings of a suitable height to close in the work will have to be made. If the curb has not been laid level, or from any cause the tubbing has not been built uniformly, the last space then becomes of variable height, and a special pattern for each segment becomes a necessity. The building up being complete, all the joints are wedged with dry soft pine wedges, first the horizontal, then the vertical, until it is almost impossible to enter a steel point. Each segment has in the centre a small hole for convenience of handling, the lower course having larger ones, that the pressure may not be brought upon the tubbing until the work is complete. These then are plugged up, beginning at the bottom. Where there is more than one setting it is in all cases necessary to connect them to permit the flow of water or air from one to the other. Concrete is used to fill in behind, giving great strength to the work. As illustrating the method of sinking through water-bearing measures by the English system, no better example can be had than of the Mur-

ton Winning, in the county of Durham. This work, consisting of three shafts, was begun in 1838, and pursued under great difficulty until complete. Engines and pumps were employed equal to 1478 horse-power and 10,000 gallons per minute. For further details see *Winning and Working of Collieries*, by Matthias Dunn.

The same plan of operations was used by my father in England in sinking the Exhall shaft. The tubbing was founded at 411 feet from the surface, and built to the height of 183 feet. Upon this was built 168 feet of brick coffering 14 inches thick, and 60 feet 9 inches deep. The water stood at 351 feet above the foundation of the tubbing. The heaviest pumping done during the sinking was 1646 gallons per minute, and the measures for long distances from the shaft were completely drained, so that at the Victoria colliery, about a mile distant, they took out the old and put in new metal tubbing.

The Chaudron system is an improvement by a Belgian engineer of the original invention of Kind, and is known by their joint names (Kind and Chaudron). It has been used on the continent of Europe with great success after the failure of other methods, and is now about to be adopted in England by the Cannock & Huntington Colliery Company. By this process all the operations are performed from the surface under water, the details of which it is not necessary for me to enter into, the process having been lately so fully described by Mr. Julien Deby, C.E., of Belgium, in a paper read before the Institute (page 117).

Those who will consult the latest example of shaft-sinking through water-bearing measures for purposes of mining will find but little improvement in the shape and form of application since iron was first introduced as a material for tubbing back-water. We are not bound to have the interior of the shaft perfectly smooth. The flanges should come on the inside, the joints planed perfectly true, and the segments put together with screwbolts, with a more perfect material for the joints after the manner of steam-fitting.

It is undoubtedly wrong to make the joints of wood, relying only on the wedging (and that from the inside in direct opposition to the pressure) to secure a water-tight shaft. By the former process the work would be finished in as many days as by wedging it now takes weeks; besides the cost is immense.

Shaft-sinking through water, in whatever form it may be pursued, is a costly operation, taxing not only the finances, but the ingenuity and skill of the best mining engineers of the present day. Three years ago but little was known at Goderich of the number and thick-

ness of the salt beds, the difficulties to be encountered in sinking to them, or the cost of such a work. To-day these difficulties are reduced by the knowledge obtained in putting down the borehole.

In so far has Mr. Attrill profited by opinions and advice given nearly three years since.

TECHNICAL EDUCATION.

BY LEWIS M. HAUPT, PROFESSOR OF CIVIL ENGINEERING, TOWNE SCIENTIFIC SCHOOL, UNIVERSITY OF PENNSYLVANIA.

It has given me great pleasure to read, in the papers recently published by this Society, the discussions on the subject of Technical Education, which were developed at the joint meeting held at the Franklin Institute in June, 1876; and since it was impossible for me to be present, I desire to improve this my first opportunity of adding the weight of my testimony and experience to what has been so ably presented by others. It is a subject about which the people need to be kept agitated, that their views may expand with the demands made for a higher and more thorough education. It is the public at large, the capitalist, the manufacturer, and the laborer, who are to be benefited more or less by this elevation of the standard of our professional schools, and it is but just, therefore, that the schools should look to them for the means with which to accomplish so desirable an object.

It is no doubt to the interest of a metallurgist to employ a skilled laborer who will prevent waste by properly proportioning his materials; by regulating the supplies of air and fuel; by arranging his plant in the most economical manner, and by disposing of his products to the greatest advantage. The engineer is benefited by selecting for an assistant a person able to determine the values of his factors of safety for the same materials in different forms and positions, avoiding expensive suits for damages and cost of reconstruction; he should be able to so locate a road as best to fulfil the requirements of a through traffic, and yet develop local industries. But I need not multiply instances to show what all will readily concede, viz.: the advantages of a *theoretical* education; that was fully demonstrated at the previous special meeting, but it is still an open question whether the practical instruction should precede, accompany, or follow the theory.

In carefully canvassing the opinions of the members who committed themselves on this subject, I find that *eight* were inclined to favor the first arrangement, *twelve* the second, aud *eight* the last—giving a plurality in favor of the synchronal combination of the two departments of study of thirty-three per cent. over either of the other systems. Most of the advocates of this middle course are men of experience in both practical work and professional duties, and whose faith in the ability of the schools to make it a practical success is founded upon their knowledge of the requirements of both theory and practice.

Numerous precedents are established in the technological schools of Russia, Germany, France, England, Sweden, and other countries; and so decided has been the impression made in this country by the exhibits of such institutions at the late Exhibition, that many of our instructors and their enterprising boards of trustees are using every effort to modify their rosters so as to embrace as large a proportion of practical work as possible in their curricula.

A combined course conforms to the order of nature. From the very inception of knowledge, the sound or name and the thing are associated; the senses and mind are colaborers—the first to glean, the second to direct, arrange, digest, and utilize the information thus obtained. The mind and hand are essential to the engineer, and they are constantly called upon to assist each other, and this interpreter of the mind, the hand, gives exact expression to the imaginative and inventive faculties in the only universal language, that of form, as exemplified in drawings. But that the mind may direct the hand intelligently, it must itself be cultivated, and thus taught to know what is right or wrong, good or bad, safe or unsafe, practical or visionary, and such knowledge can only be obtained by an intimate association with materials and tools, and the methods of using them, by which is developed their physical properties. To educate the mind simply by reading, as in a purely theoretical course for a number of years, and then to develop the practical requirements of one's nature, is abnormal, and a waste of time; the two assist each other by giving substance to the idea and weight to the formulas that may be used.

Another important consideration is the physical benefit conferred by a small amount of labor. The diligent student, without exercise, may graduate well, but it will be with an impaired constitution, caused by constant confinement and continuous and sometimes severe mental strain, which overtaxes and hence weakens the intellect; on

the contrary, a due percentage of shopwork not only furnishes recreation and physical exercise, but enables the student to appreciate much better the practical advantages of his theory.

It is urged by some of the advocates for separating the courses, that it is impossible to meet fully the requirements of practice in the schools. While this is undoubtedly true, much more may be taught in a practical direction than is generally imagined, and I cannot subscribe to the statement on page 52 of the Report, to the effect that "the schools should confine themselves to teaching principles only. That moment they attempt to teach their applications they are either ten to twenty years behind the age, or else they incur the ridicule of practical men by teaching how to make something of no use." This may be true of some non-progressive institutions, where the scientific periodicals never enter, and where no visits of inspection are made to workshops and structures in process of erection, but it can hardly be applied to any of our most prominent technical schools. All practical knowledge is progressive, and the sooner a student begins the better will be his chance of success. It is only by knowing what has been done and what has failed, with the reason why, that he can proceed rapidly to add to the general fund of invention or discovery. The greater the number of elements he possesses, the larger will be the number of possible practical combinations; and if the practical men will not furnish these elements, they must not expect from the schools such men as they desire to assist in developing their industries.

The statement is also made that "before eighteen or twenty years of age the body is not generally sufficiently developed to endure the physical hardships of engineering." My own experience was so totally at variance with this, that I hope I may be excused the egotism of remarking that I was but a boy fourteen years old, only four feet nine inches high, and hardly more than an animated shadow, from the effects of intermittent fever and too much study, when my father took me from school and gave me a level rod, almost as heavy as myself (at least so it seemed), and so tall that I could not reach the target at the top, to operate on the Troy and Boston and Troy and Greenfield Railroads, in Massachusetts, during some severe fall and winter weather. Had I consulted my own comfort and convenience I should have preferred anything else, but I was obliged to weather it through whether I would or not, and it was, doubtless, the best school I ever attended.

A fellow-member remarks, on page 63, of a blast furnace manager, "though he may have efficient subordinates in various departments, he must be able to understand and check their work, and he will find it extremely useful to be something of a mason, bricklayer, and carpenter, largely a surveyor, engineer, and mechanic, and well up in the general principles of chemistry and metallurgy." This I can heartily indorse, but I do not entirely approve the method proposed for acquiring such varied knowledge, for the report adds: "After the school-*practice*." Graduates, as a rule, are above mixing mortar, laying bricks, framing timbers, etc., but all this they can be made to do willingly if incorporated in their course, and their tutor is the right sort of man, and will *show* them how.

But this introduces the difficult element of finding capable teachers. It requires that they shall be practical men as well as scholars, and it is one of the chief obstacles to the successful establishment and operation of technical schools. If a man is a successful practitioner, and has the requirements of a good teacher, there are no schools that can hold out sufficient inducements for him to close his business and consent to teach. Again, there are many who are *too practical* to teach, having, as they say, "grown rusty on their mathematics," and most of those now engaged in teaching have not the experience required to do justice to so expanded a course of instruction. For the present, however, the difficulty may be met by calling in the service of some expert or foreman to explain the tools and their uses, and to direct students in their efforts to use them. A few weeks of such practice, with carefully prepared notes and sketches, would give them a fund of information they could never gather from books, and would do much towards breaking the ground for further cultivation by the professors. To accomplish this would require a small endowment, to be disposed of in a manner similar to the Whitworth scholarships in England.

Besides his practical knowledge, the engineer must be a man of integrity and good judgment, with experience in the management of men, and a financier. Most of these requirements can only be taught by combining theory and practice, organizing students into squads, gangs, or parties, and appointing one of them foreman, who directs the workmen in their several duties. By comparing the cost of a piece of finished work with the estimates, they learn the value of labor and materials; and so, in many other ways, can the workshop be made to supply a great defect in the older methods of education.

With reference to æsthetics and art instruction, the greatest

obstacle to progress arises from the apathy of the class intended to be benefited, the manufacturers, who, to protect themselves from competition, hesitate to furnish the information required to make such instruction practical. Hence it is that the remark is often heard that the designs of certain schools are pretty but impracticable. To overcome this defect to a certain extent, the Franklin Institute sent out the following circular to such of its members as would be most apt to respond favorably, but in return only a few drawings were received from a single firm :

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September, 1875.

DEAR SIR: In view of the great demand for a better class of designs in our American manufactured articles, it is proposed to give especial attention to this subject in the Franklin Institute Drawing School during its coming sessions.

In furtherance of this object, it has been decided to request from manufacturers of textile fabrics, paper-hangings, porcelain, etc., the donation of such articles as will exhibit the necessary elements of design, such as structure, form, color, etc., with any suggestion they may be pleased to make as to any special requirement which must be fulfilled to make a design of *practical* value.

Donations are also requested from manufacturers of machinery of all kinds, of drawings or models that will serve as examples of mechanical drawing, representing modern practice in machine building. Any service that you may render the Institute, either by donation or information, will be properly acknowledged.

Respectfully yours,
J. B. KNIGHT,
Secretary.

Until we can have a better understanding and more perfect co-operation between manufacturers, engineers, and teachers, we cannot expect to make much progress in our efforts to educate men who may practice successfully from the date of their graduation.

In conclusion, I have only to suggest that it would be a step in advance if such organized societies as this were to identify themselves with the educational institutions teaching kindred subjects, and by the appointment of a committee on Technical Education see that such information was placed within reach of those institutions as would assist them in keeping up with the progress of the age, and enable them to introduce, explain, and exemplify the latest advance in methods and processes, by giving publications, pamphlets, drawings, photographs, models, ores, or manufactured articles to such schools ; prevailing upon manufacturers to open their doors for visits of inspection by students, and assisting the latter to secure positions after graduating, by keeping a register of their names and addresses.

The books thus given would form part of a circulating library on

scientific subjects, and be of much greater use than such works usually are when kept for reference merely. All growth is gradual, and all innovations are progressive. If this paper merely serves to increase the interest of practical men in the efforts made by instructors to raise the standard of the schools and increase their usefulness by enlarging their resources, it will have accomplished its purpose. The tree will be known by its fruit.

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*THE NOMENCLATURE OF IRON.**

BY HENRY M. HOWE, A.M., M.E., TROY, N. Y.

In discussing the classification of iron to-day, we are to leave out of consideration the general division into non-malleable or cast iron and malleable iron, as to the adequacy of which no question has been raised; and to confine ourselves to the subdivisions of malleable iron. This has been classified, according to the extent to which the properties imparted by carbon are present (viz., resilience, hardness, strength, and, above all, the capacity for being hardened by sudden cooling from a high temperature), into (1) wrought iron which cannot be hardened, and (2) steel which can be hardened; and this classification I shall, for briefness, term the carbon classification. Until within a few years all authorities, both metallurgical and general, have concurred in explicitly recognizing the carbon-given qualities, and pre-eminently the capacity for being hardened, as the essential qualities of steel; this is laid down with clearness by every writer on the subject.

For several years this old classification has not been sufficient to meet all our needs, since the genius of Bessemer, Siemens, and, I may add, Holley, has produced wrought iron which has been perfectly melted, and thus freed from certain mechanical adhering impurities. This causes what we call homogeneousness for want of a better word, and gives rise to many important qualities which the old wrought iron had not; qualities universally recognized, though not readily described. I shall, for briefness, style them the fusion qualities, and a classification based on them, a fusion classification.

These qualities render the new product so vastly superior, for most purposes, to the wrought iron formerly known, that it is neces-

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* This paper was read in opening the discussion on the motion to adopt the report of the International Committee on the Nomenclature of Iron and Steel. At the conclusion of the discussion the resolutions on page 44 were adopted.

sary to arrange the nomenclature of iron so as to indicate their presence or absence in any lot of wrought iron under consideration.

Now, this new wrought iron possesses no one of the qualities which were acknowledged essential to steel, as contrasted with wrought iron, viz., the power of hardening to a considerable extent, greater strength, hardness, resilience, etc., and it possesses every one of the properties which were admitted to be essential to the old wrought iron as contrasted with steel, viz., inability to harden, considerably lower tensile, compressive, etc., strength, lower resilience, etc.

However, the new wrought iron has several qualities which were incidentally present in some of the varieties of steel, absent, however, in the others, and always absent in the wrought irons formerly made, viz., it is made in the same furnaces in which some varieties of steel are made, but in which none of the old wrought irons could be made, and in which many of the old classes of steel could not be made. So cake is made in the same pans that bread is. It also has practically perfect homogeneousness, which some of the old steels had, which many of the old steels could not have, and which none of the old wrought irons had.

That it has any other qualities which the old wrought irons had not, and which the old steels had, I deny. I challenge the mechanical engineers to produce evidence tending to disprove these positions, or to show that homogeneousness was ever considered essential to steel.

Now, certain mechanical engineers and manufacturers, many or most of whom were pecuniarily interested in attaching the name steel to the new products, because that name was associated in the mind of the public with superiority, have called these new products steel, in full face of the fact that they had none of the essential qualities of steel, and all of the essential qualities of wrought iron. They have called them steel, partly because made in the same furnaces that steel was; partly because they are homogeneous (while many of the old steels could not be homogeneous), and partly for commercial reasons. Metallurgists have generally concurred in calling them steel under silent protest, because no other name was offered, and because they were offered for sale as steel, just as we have spoken under silent protest of "silicon steel," knowing that it was not steel, and that it had practically no silicon; or as a naturalist might speak to a fisherman of a whale as a fish, knowing all the while that it was not a fish, but a mammal. Not content with this, these mechanical

engineers have coolly proposed a nomenclature which should class these new wrought irons as steel, and should class many of the varieties of steel as wrought iron, basing their classification on the presence or absence of homogeneousness, a quality never considered essential to steel, and disregarding every one of the qualities which have heretofore been deemed essential to steel. They say that blister steel, shear steel, puddled steel, and German steel are now, to please their mechanical majesties, wrought iron.

Now, several metallurgists have protested against this gratuitous upsetting of the landmarks of our metallurgical language, and have replied to the mechanical engineers that it would seem wiser not to throw away the well-settled and useful division of the iron-carbon products into wrought iron, etc., but to supplement it by employing some new term to indicate the presence or absence of the qualities which have newly become so useful and prominent in their new wrought iron.

We have urged that the gratuitous change they propose will destroy the very convenient general carbon classification which can perfectly well coexist with a supplementing fusion classification, and that the change would cause much needless confusion and inconvenience.

At Prof. Egleston's wise suggestion, an international committee has proposed the nomenclature we now discuss.

I have arranged these three classifications—the original one, that of the mechanical engineers, and that of your committee—so as to show their relation to each other, omitting the less important varieties of iron for brevity. I have first arranged the more important varieties of malleable iron in the way which a strict adherence to the old classification would necessitate; and throughout the table I have given in capitals the varieties which come under the head "steel" of this classification, and in italics those which here come under the head "wrought iron."

MALLEABLE IRON.

Original Classification.

I. *Cannot harden—wrought Iron.*		II. CAN HARDEN—STEEL.
Puddled Iron		BLISTER STEEL.
Bloomary Iron		PUDDLED STEEL.
Malleable Castings.		SHEAR STEEL.
Bessemer Iron.	CAST STEEL.	BESSEMER STEEL.
Martin Iron.		MARTIN STEEL
Crucible Iron.		CRUCIBLE STEEL.

Mechanical Engineers' Classification.

I. Has not been fused—wrought iron.	II. Has been fused—steel.
BLISTER STEEL.	*Bessemer Iron.*
PUDDLED STEEL.	*Martin Iron.*
SHEAR STEEL.	*Crucible Iron.*
Puddled Iron.	BESSEMER STEEL.
Bloomary Iron.	MARTIN STEEL
Malleable Castings.	CRUCIBLE STEEL.

International Committee's Classification.

I. *Cannot harden—Iron.*			II. CAN HARDEN—STEEL.	
Puddled Iron. *Bloomary Iron.* *Malleable Castings*	A, has not been fused—*Weld Iron.*	Weld Metal	A, has not been fused—WELD STEEL.	BLISTER STEEL. PUDDLED STEEL. SHEAR STEEL.
Bessemer Iron. *Martin Iron.* *Crucible Iron.*	B, has been fused—*Ingot Iron.*	Ingot Metal.	B, has been fused—INGOT STEEL	BESSEMER STEEL. MARTIN STEEL. CRUCIBLE STEEL.

The steel of the mechanical engineers' classification, it will be seen, embraces three important varieties of wrought iron of the original classification; while the wrought iron of the former has also three of the varieties of the steel of the latter. The violent metathesis, this changing altogether the grouping of the varieties, thus taking three varieties from the class steel and replacing them by three entirely dissimilar ones, is what Mr. Holley calls *enlarging** the term steel, and seriously compares it with embracing anthracite under the head of coal; saying that anthracite does not cake in burning, while bituminous coal, which was the first in general use, does cake. The trifling difference between the cases, that anthracite has every quality which was considered *essential* to coal before anthracite was used, while the new wrought iron has no one of the properties which have been always recognized as essential to steel, and every one of those which have been recognized as distinguishing wrought iron from steel; and the difference that the recognition of anthracite as coal removed no other species from the class coal, while to call the new wrought iron steel compels Mr. Holley to remove three species from the class steel to the class wrought iron—these trifling differences, of course, do not interfere with the aptness of Mr. Holley's simile; any one who cannot see the parallelism of the two cases must be suffering from mental stra-

* Trans. Am. Inst. Mining Engineers, vol. ii, p. 138.

bismus, and I suggest his visiting Dr. Brown-Séquara to nave his thinking apparatus put in order.

Examining the original classification, it will seem that the first three species, both of its wrought iron and of its steel, have not been fused, while the last three have been. Here, then, we can easily introduce a fusion classification, by dividing at once (I) the wrought iron and the steels into (A) weld metal, which has not been fused but merely welded together, and (B) ingot metal, which has been cast into malleable ingots when fluid; the ingot metal into (I, B) ingot iron and (II, B) ingot steel, and the weld metal into (I, A) weld iron and (II, A) weld steel. This is precisely what your committee has done, as will be seen by comparing their classification with the original one.

As to the merits of this classification I will only say that (recognizing the necessity of indicating the presence or absence both of the fusion and of the carbon properties) while it does not disturb the existing carbon classification, it supplements it with a simple fusion classification, which is quite independent of it, the two being co-ordinate yet distinct. The compounding of the two can give rise to no confusion; and the terms of the former are practically the same as heretofore, the terms weld and ingot of the latter being simple, clear, and concise. The compound terms indicate clearly and tersely, in every case, the presence or absence at once of the carbon qualities and of the fusion qualities. It introduces a new, inevitable, and necessary element into the classification, without disturbing the previously existing elements.

We have now a not unimportant duty. These two classifications, the one proposed by the mechanical engineers, the other by our own committee, have been offered, and it rests with us to decide, once and for all, the nomenclature of iron. It is almost inevitable that one or the other of these classifications should be henceforth adopted, either as they are now before us, or as they may be modified by us. It is imperative and absolutely unavoidable that the present nomenclature should be so modified as to make the new product a distinct class by itself.

The question is, How can this new class be introduced with the least difficulty and confusion, and yet leave the classification of iron clear and systematic? Whether this change shall be made in the rational, wise manner advised by your committee, or in the irrational, confusing way into which the iron manufacturers have stumbled, and of which a portion of the public has heard enough to muddle its ideas, it is your duty to decide. The present is a rare

opportunity for you to exercise wisely and calmly an all-sufficient power in simplifying the nomenclature of this most important branch of metallurgy; a nomenclature which is in constant use with a very large proportion of the civilized world.

Unlike the introduction of the metric system, your committee's classification will introduce no radical changes; for the old words, cast iron, steel, and wrought iron, will mean precisely what they have always meant to the whole world until within a few years, and what even to-day they mean to all but a small fraction of those who speak them. And even to this fraction, the change will not be a trying one. For the name of the new wrought iron, which they have called steel, alone will be changed for them, and it will be called iron, with which it has every property in common, instead of steel, having with the steel with which they are most familiar only the property of homogeneousness in common.

I repeat, it is a rare opportunity. Your committee's classification, if adopted, would be sent out with great weight. The unanimity of so competent, so impartial, so well-known, and so universally respected a set of men, truly representative men of so many different countries and races,—the Scandinavian, the Anglo-Saxon, the Teutonic, the French,—will carry great weight. The ready acceptance of the classification by the Germans, even without your approval, assures us of the ease with which it would be universally adopted, if sanctioned by so august and competent a body as yours; especially if your members (many of whom are so very influential in the iron industry) exert their individual influence to promote its acceptance and introduction. If the classification of the mechanical engineers is to be rejected, now is the time to do it—to nip it in the bud before it has got saddled on us, and to offer in its place your committee's classification. To reject the latter would be regarded as a virtual acceptance of the former by its energetic advocates.

The great objection raised against your committee's report is that it retains the established classification, based on the extent to which the carbon properties are present. The essence of Mr. Metcalf's eloquent and able attack at the last meeting was:

"The committee's classification is unscientific, because it separates wrought iron from steel, according to the extent to which the carbon properties are present; these classes must shade into each other, and you will have to separate them by an arbitrary and, therefore, unscientific and unendurable line.	"The mechanical engineers' classification is scientific, and it separates cast iron from steel, according to the extent to which the carbon properties are present; these classes must shade into each other, and I shall be able to separate them by an arbitrary (and therefore scientific and gratifying?) line!

"Let us leave deep argument to those who will not swallow my consistent classification."

Mr. Holley has given us much more in the same vein, ending with the grand dictum: "The names of new materials and processes, like the laws of trade, are not fixed by the arbitrary edicts of philosophers, but are gradually developed to meet the general convenience."

This is the great and constantly repeated charge against a carbon classification, indeed the only charge worthy of the name of argument, viz.: that its classes inevitably shade into each other, which makes it so intolerable that its very terms are to be appropriated for the needed fusion classification. This arises from what seem to me philological misconceptions, and it must be discussed, not on mechanical or metallurgical, but on philological grounds.

Classifications are based upon important differences between the classes they separate. Occasionally the differences between classes are so marked in all cases, that we can divide them easily by a very broad line, and that there are no intermediate cases which lie near the dividing line. Such are our divisions of most animals into male and female, of words into monosyllables, dissyllables, etc.

By far the greater number of classifications, however, including the greater number of the most useful and important ones, are to a greater or less extent arbitrary. Even most of those which at first sight appear most clearly marked, on further examination are found to separate classes which blend into each other imperceptibly. Such are our most important divisions in natural science, and such are most of the most valuable and useful classifications employed in the arts.

Thus, on examining our divisions of organic matter into animal and vegetable, of matter into liquid, solid, and gaseous, of phenomena into physical and chemical, of animals into vertebrate and invertebrate, and a thousand others which at first sight seem to be very broadly and clearly marked, we find that, in the cases of certain sensitive plants, of sea-anemones, of sponges, etc., the classes animal and vegetable shade into each other; in the cases of viscous liquids, there can be no sharp line between the liquid and solid states, except it be an arbitrary line, for the glaciers teach us that even ice can flow; so between the finely divided liquids which we see in mists and true vapors, and again between vapors and true gases, the divisions must be made arbitrarily, if at all; in certain cases we find that the lines between molluscs and vertebrates must be arbitrary, though these classes seem so utterly dissimilar, as must also the division between

the milder forms of chemical action, such as solution and purely physical action. Yet these are eminently proper and scientific classifications. We divide the spectrum into red, orange, yellow, green, blue, and violet; yet how can we separate red from orange, or blue from violet, or greenish-yellow from yellowish-green, except by purely arbitrary lines? And who will deny the usefulness of this classification of colors? We divide coals into anthracite, semi-bituminous, bituminous, lignite, peat, etc.; yet do not these useful and appropriate classes imperceptibly blend into each other? Must not almost all the classes of lithology be separated by arbitrary lines, if at all? How else can we separate silicious limestones from calcareous sandstones, or hornblendic granites from micaceous syenites, or bituminous shales from shaly coals, or crystalline from fragmental rocks? Very many of the classifications of chemistry, mineralogy, metallurgy, biology, physics, and indeed of every branch of natural science are necessarily more or less arbitrary. I would ask these gentlemen if they have found it so very inconvenient to divide spiegelcisen from ferro-manganese, or foundry from forge pig, by arbitrary lines? Or do the copper smelters find life intolerable because coarse metal, blue metal, white metal, blister copper, dry copper, and fine copper shade into each other imperceptibly?

Thus classes are formed which possess, each within certain limits, the qualities on which the classification is based, and these limits may be more or less exactly agreed upon according to the nature and requirements of the case. The reason why divisions must generally shade into each other, and why dividing lines must usually seem arbitrary, is that most important qualities (qualities so important that the convenience of thought and language make it desirable to indicate, by classifications based on them, their presence or absence, or the degree to which they are present) exist in proportions which increase gradually, if not uniformly, from sub-variety to sub-variety, or from individual to individual, by very small or even infinitely small increments, without sudden or marked breaks anywhere which can serve as broad dividing lines between classes. When we wish to indicate to what extent such a property is present, we are forced to use arbitrary divisions. This is due to the nature of things, and not to the arbitrariness or tyranny of philosophers.

Now, I will not deny that classifications *as such* would be more convenient if nature had dropped out all the things which lie near our lines of demarcation, and had allowed us to separate our classes by broad and plain dividing lines. But as she has not, for the pur-

poses of expressing our thoughts it is necessary to make use of arbitrary lines of division. For all our needs these classifications are clear enough, although they do blend into each other.

To reject all arbitrary classifications would be to make speech impossible, to destroy language itself.

To say that it is unscientific to classify iron according to the extent to which it has the carbon properties, simply because the groups would shade into each other, is idle. It shows an ignorance or forgetfulness of the classifications which science has made, and the inability or unwillingness to compare the classification we are discussing with those without which our daily conversation would be impossible.

It is rather amusing to note that the carbon classification is charged with being unscientific only by men who rather boast that they are practical and not scientific, while nearly all those who call themselves men of science defend it.

It is most astonishing that such men as Mr. Holley and Mr. Metcalf should bring forward such an objection seriously, and that Mr. Holley should say, "Obviously no two men can agree on the amount of any hardening element which may constitute steel."* Why not? There is no reason why they cannot agree on that point if they wish to.

Nor is it so necessary that they should agree. Are men agreed as to the exact position of the line which separates bituminous from anthracite coals, or beef from veal, or spiegeleisen from ferro-manganese, or horses from colts, or sandstones from quartzites, or milk from cream, or magnetites from hematites, or fresh eggs from stale eggs, or metallurgy from chemistry, or mechanics from engineers, or music from discord, or cake from bread, or gun-metal from bell-metal, or metals from metalloids, or conductors from non-conductors, or the English from the Anglo-Saxon language, or dolomites from limestones, or mush from porridge, or brooks from rivers, or mountains from hills? Does not "the importance of a quality here make the existence of that quality a definite basis of classification when it exists in both classes, gradually increasing in one and decreasing in the other, and being practically the same near the dividing line?"† And are not these useful, convenient, and in some cases absolutely indispensable qualifications?

Mr. Holley says: "A very serious objection to the proposed divi-

* Trans. Am. Inst Mining Engineers, vol. ii, p. 141, l. 15.

† Ibid., p. 146, l. 28.

sion is that it occurs about midway in a range of structural steels."* Do not the divisions of metalloids from metals, of blue from violet, and many other of the divisions I have enumerated, in an exactly parallel way occur midway in ranges which are in constant use, without diminishing their value or usefulness? [The dividing line between wrought iron and steel is placed at the point of 0.30 per cent. carbon, because, as Karsten has shown, this is a critical point in the curve representing the degrees to which differently carburized varieties of iron possess the carbon properties.]

Had the gentleman said that a carbon classification was valueless because the carbon-given qualities are unimportant (and I think no one has been so indiscreet), the charge would have needed answering; for, since the use of a classification is to indicate whether the property (or properties) on which it is based is present or absent, or to what degree it is present, the importance of that property determines the importance of the classification. Until the carbon qualities have ceased to be important, there will be a need and a use for a carbon classification.

But the claim that it is to be given up simply because its classes blend into each other cannot be discussed, because it is not a valid objection.

Unless the gentlemen will undertake the difficult (because impossible) task of showing why a blending of its classes, and a division at a salient point which occurs midway in a range, should affect a carbon classification in an entirely and radically different way from that in which perfectly parallel blendings and divisions affect thousands of perfectly parallel classifications, such as I have cited, they are logically forced to acknowledge that this blending and division of the carbon classification is not incompatible with a high degree of usefulness, or even with absolute indispensableness.

If we were prevented from having more than one classification of iron (a contingency not likely to arise), and were thus compelled to choose between several classifications, based on equally important properties, then the fact that one classification admitted of much more broad dividing barriers than the others might weigh in its favor. But there is no question as to the propriety in this case of having both a fusion and a carbon classification, except that the retention of the latter would prevent the mechanical engineers from using its terms for the former.

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* Trans. Am. Inst. Mining Engineers, p. 147, l. 3.

On this head Mr. Holley has said, "Whitworth has proposed to divide wrought iron from steel at the point of 28 tons tensile strength," and asks triumphantly: "How would Mr. Whitworth like to order gun-steel by this definition?" How would Mr. Holley like to order razor-steel, or even rail-steel, by his own definition? At our last meeting he said in the same vein, "This carbon classification is of no earthly use, for, practically, when one orders steel, one specifies the percentage of manganese and carbon desired," or words to that effect.

When one wants a horse that has run inside of 2.18, one does not merely order an animal, nor a vertebrate, nor a mammal, nor a quadruped, nor even does he merely vaguely call for a horse. He describes explicitly what he seeks. Yet these broad and general classifications of animals, vertebrates, mammals, quadrupeds, and horses have their value, and form a necessary part of language, though they are not universal machines, and though they do not describe things minutely. So our broad carbon classification into iron, steel, and cast iron has its value and use, though it may often be necessary to use more explicit terms in describing particular lots of iron. And precisely similar necessities for the use of specific terms would arise were the classification of the mechanical engineers in use. But, supposing the carbon classification to be utterly useless, and therefore to be formally abandoned, I cannot see the wisdom of seizing its names for the classes of the fusion classification.

The advocates of the mechanical engineers' classification are men of most marvellous mechanical ingenuity: have they so little philological ingenuity that they cannot invent an appropriate name for the new product they have given to the world? Can they not, or will they not? Will they not accept one that is offered to them? Or have they such a lusting to call their new product steel that they will not only blot out the carbon classification, but also ravish its names? Whenever a new discovery is made are previous classifications to be destroyed and their names to be appropriated for describing the new thing? Or would it not seem more sensible to amend and supplement our existing classifications so as to introduce the new element while preserving the old ones? Shall not the old names be kept for the old things, and new ones found for the new things?

The case seems to me like this: Disregarding, for the sake of illustration, the European and Asiatic coal-fields, let us suppose that the Virginian Carbonite had really turned out to be an enormously

valuable mineral, as was prophesied, and so far superior to ordinary semi-bituminous coals as to make it necessary to apply some special name to it, such as carbonite, and that it really deserved to rank as a new class in the classification of coal. Suppose a great number of coal miners, without any great geological pretensions, should say to Dr. Hunt, or to his geological congress at Paris: "Gentlemen, we find that the classification of coals into anthracite, semi-bituminous, bituminous, lignites, peat, etc., etc., is wholly beastly and unscientific, because we find that anthracites shade into graphite on the one hand, and into semi-bituminous coals on the other, as do the latter into bituminous coals and anthracite, etc., etc. This is vile. We coal miners are going to adopt a wholly new and beautiful classification. This is so much more charming than the present one that the latter has forfeited all claims to its names, which we will use for our new classification, which the coal miners have used these five years. We do this, first, because it is a shame not to call the newly discovered coal cannel coal, for it is a really charming and most superior coal, as superior as the new kind of wrought iron is to the old; and we are all sure that it will sell better if we call it cannel, which is higher priced than ordinary bituminous coal. Secondly," triumphantly, "if you do not call it cannel, what would you call it? We propose to call all coal found in New England lignite; it has none of the properties formerly associated with lignite, except that it is an inferior coal, which, like puddled steel and blister steel, is not much used now, and is not worth fussing about. All found in the Appalachian range and in the Middle States we call cannel coal, because it is very superior, and is all quite free from sulphur; quite as the new wrought irons are free from slag. All found in the Western States east of the Mississippi we call bituminous, because they are inferior to the Middle States coal, but better than the New England coal; and all west of the Mississippi, anthracite. This is the only practical classification."

Dr. Hunt replies that "it would be wiser to preserve for the old classes the old names, and, if necessary, invent a new name for the newly discovered valuable coal, and supplement the existing classification so as to make this a distinct class." "That a geographical classification is perhaps desirable, but that there is no reason why it should not coexist with the present classification; and certainly no reason why the terms of the latter should be used for the proposed geographical classification, which would better have a new set of geographical names; just as the desired fusion classification of iron

would better have a new set of fusion names which will confuse no one."

They reply that "they are simply '*enlarging*' the term 'cannel,' really nothing else; that the names of new materials are gradually developed to meet the general convenience, and to tip over all existing and therefore useless classifications, and not according to the senseless edicts of arbitrary, unreasonable, and despotic philosophers."

Have philosophers—which term I interpret as meaning men of science—nothing to say about scientific classification of things that happen to be commercially valuable? In comparing our simple system of weights and measures with its long ton, its net ton, and its miner's ton, its avoirdupois, its troy, apothecaries', and diamond systems of weights, its liquid, dry, cubic, and fluid measures of volume, its statute, Gunter's nautical, and cloth linear measures, its hundreds of different bushels, its scores of different gallons—in comparing this simple and practical system of weights and measures, which the Anglo-Saxon race has developed to meet the general convenience, with the foolish, theoretical, unpractical metric system which the arbitrary edicts of tyrannical philosophers have imposed on the slavish hordes of Europe, one feels the wisdom of Mr. Holley's dictum.

Like the question of the metric system, you are to decide whether the world shall have a simple, rational nomenclature for iron, or whether it shall have the irrational one advocated by the mechanical engineers. Unlike the metric question, you have not to ask, Will it pay to displace the present system for a better? but merely to decide which of two practically new systems you will sanction—the one, like the metric system, the calm choice of able men; the other, like our present weights and measures, the confusing outgrowth which tries to meet general convenience; the one introducing the minimum of change with the new necessary element; the other introducing the new element at the expense of the old ones.

The propriety of your arranging the nomenclature of the metallurgy of iron in the way which seems to you best and most systematic, be it against the protest of the ironmasters, is quite as clear as was the duty of the chemical world to systematize its nomenclature, in spite of the protests of the chemical manufacturers, as it has just done, amid the applause of the world.

And your right to call the new wrought iron "ingot iron," although the ironmasters have called it steel, is as clear as the right

of the naturalists to say that a whale is not a fish, but a mammal, though the fishing industry does style it a fish.

MR. JAMES PARK, JR., of Pittsburgh, said: I have listened with much interest to the well-written and interesting paper read by Mr. Howe, and congratulate my friend upon his effort to demonstrate his views in relation to a nomenclature of iron and steel; yet I regret that, in the remarks I have to make, I will be compelled to dissent materially from the views entertained by him as to the proper classification of iron and steel. I came to this city full of apprehension, fearing that this Association might take such action in reference to this question as would not only compromise its members, but create confusion in the trade. The American Institute of Mining Engineers is now a power in the land. When I look back but a few years, when I had the honor of first meeting it at Pittsburgh with a brief address of welcome, I am greatly pleased and feel proud to have the opportunity of uttering a few words before it now in its present almost gigantic dimensions. The few minutes I shall claim your attention shall be occupied in defence of the useful article of cast steel, and in protesting against it being robbed of its good name. I did fear that some action might be taken by this Institute which would bind it before the public, but at the opening session last night I was greatly relieved when you, Mr. Chairman, made known to us that, through the wisdom of the framers of our rules, the Institute is prohibited from taking action which will in any way bind it, by the votes of members present at any meeting. I cordially approve of your decision, and feel glad that this wholesome provision exists, and that it will prevent the establishment by the Institute of a nomenclature of iron and steel, which action, in a legal point of view, would be important and dangerous. That soft steel, or steel containing a low percentage of carbon, when cast, deserves the name of cast steel, no one should deny. It is known to all that the human body contains a certain quantity of blood, and that the blood contains a certain quantity of iron (whether it is "weld iron" or "ingot iron," I leave to the scientific gentlemen who recommended the new nomenclature to determine); and that the quantity of iron in the blood of persons comprising the human family varies, no one can call in question. One man has more blood and more iron in his blood than his neighbor; and it is admitted that the blood and iron in some men amounts to a small percentage

of that in others; yet, it matters not how little the quantity the life-giving element may be reduced to, we call him man. As well might we propose to call the man who has little blood or iron in his blood by some other name than man, as to give steel containing a small percentage of carbon another name than that it is entitled to, viz., steel; or if cast, "cast steel." As blood is not an entirely homogeneous fluid, I suppose the iron it contains should, under the new nomenclature, be called "weld iron." Practical manufacturers and workers in iron and steel, in this country, cannot be prevailed on to adopt the new nomenclature, and will view such a classification as that recommended by the committee, or that proposed by Mr. Howe, as being far from an improvement upon the plain and easily understood nomenclature now universally in use, and likely to remain so for hundreds of years to come. I feel gratified to learn from Dr. Hermann Wedding's letter, recently published in the *Bulletin of the Iron and Steel Association,* that our good friends in Germany "are made happier" by reason of the adoption in their country of the nomenclature; and yet, because of this, we need not make ourselves miserable by reason of retaining the present sensible and practical nomenclature, acknowledged to be such by all manufacturers and consumers of iron and steel throughout this country. I can easily understand why it seems so difficult to agree upon a new nomenclature of iron and steel. The reason is apparent, and the diversity of views expressed gives rise to the question, Why introduce a new nomenclature when we have already a better one than any new one which could be devised?

Mr. H. M. Howe.—In reply to Mr. Park's statement that the meaning given to steel by the mechanical engineers was accepted universally, I would say, I deny the assertion, and I claim that the property formerly recognized as essential to steel—that of hardening—is still so recognized by the community, with the exception of those immediately connected with the manufacture and sale of the new variety of wrought iron. Foreseeing that this point would be raised, I have obtained some statistics bearing on it. I went to a large machine shop last week, and considering that the average New England machinist would represent fairly the opinion of the community at large on this point, I presented the following questions in writing, singly, not putting the second till the first had been answered, to the superintendent, three draughtsmen, the foreman, fourteen machinists, and six carpenters, all taken entirely indiscriminately, without having held any previous communication on the subject

with any of them, and not allowing any one of them to hear or know the answers of any of the others: "Do you consider that steel is necessarily a kind of iron which is capable of being hardened or tempered, so as to become harder, stiffer, and more springy than ordinary wrought iron?" Eighteen answered "Yes," without any explanation. I think it is not a leading question. Five more answered this question "Yes," after I had explained it by means of the second one, "If a piece of metal was given you, represented to be steel, and you found that it could not be hardened at all, so as to be made harder than wrought iron, would you consider it steel or wrought iron?" Twenty-three answered unhesitatingly that it could not be called steel, but would undoubtedly be wrought iron; one carpenter did not know positively, and a second carpenter had heard that Bessemer steel sometimes could not be hardened. Thus ninety-two per cent. of a lot of men of more than the average intelligence, and all accustomed to using iron and steel, confirmed my position that the original definition of steel is the one now almost universally recognized.

MR. PARK.—I would remind Mr. Howe that it is important to know not only what the purchaser who orders or workmen who use steel answer when asked "what steel is," but what they order when they want a certain product, and what they pay for. I have never known an instance where soft cast steels are wanted that the order is given for them by any other name; the word "iron" or "metal" is never used in connection with them. My friend Mr. Howe is in error in concluding there is anything new in the so-called "new products." Soft cast steel containing as low as two-tenths of carbon and even less was made and sold in large quantities before Kelley or Bessemer made their first blows, and, of course, before the open hearth furnace practice was heard of. This product was used by the Pennsylvania Railroad Company and others in this country before a pound of soft cast steel was produced either by the pneumatic or open hearth practice, not only in an experimental way, but in large quantities. It is true that new appliances for producing these soft cast steels have been devised, but the product is the same as heretofore. Soft cast steel has been called by the steel manufacturers "Homogeneous cast steel," and by the steel melters throughout the country, I believe, "Hold Virginia Steel," not "Homogeneous metal" as Mr. Howe understood some melters at my works to name it. In this I feel sure he is mistaken, as I never heard it designated by any steel melter by any other name than that curious one I have

mentioned. As to the conclusion, as I understand Mr. Howe that it is not necessary that cast steel should be homogeneous, I can only say that without this quality it would be about worthless.

It is the great aim of the steel manufacturer to make his product entirely homogeneous, this being demanded by all who use cast steel. If the manufacturer cannot accomplish this desired result, his customers would cease to order or use his steel. To call these soft cast steels, made, as they are, by fusion, "ingot iron," strikes my mind as being absurd. I agree, however, with Dr. Raymond in his criticism on the term *Homogeneous*, and admit that what is really meant is absence of fibrous structure. I am sure Professor Egleston is aware that a large quantity of American iron—properly known as "wrought iron"—is manufactured which will not weld, and I feel just as sure his good judgment will indicate to him that the term "weld iron" is inapplicable, and that he will not urge the use of this term as applied to "wrought iron." Let us avoid giving new names to old articles of manufacture, but endeavor to retain those already well understood by all who produce and use them.

MR. HOWE.—In reply to Mr. Park's statement that fused wrought iron was not a new product, I would say, although wrought iron had been melted prior to the introduction of the Bessemer process, it was on so small a scale and under such exceptional circumstances that it did not deserve to rank as a separate class. This is shown by the fact that before that period it was mentioned by metallurgical writers only as a very unimportant subvariety of wrought iron. They certainly never classed it as steel.

DR. R. W. RAYMOND.—It seems to me that the terms "wrought iron" and "wrought steel" could be retained instead of weld iron and weld steel, which are both new and liable to misconstruction. An evidence of this is the fact that in this debate they have already been construed to refer to the property of welding possessed by the metal. I would not undertake to decide hastily upon a point of this kind; and, if "wrought iron" does not fairly cover all that was meant by "weld iron," I would give up this view. In the discussion on this subject at the June meeting in Philadelphia it was suggested that "wrought iron" would not include blooms; but from this view I beg leave to differ. Homogeneity either means the absence of all structure, or the uniformity of appearance and structure over a single section. In the first sense it is not true of any steel, nor is it a result of fusion and cooling. In the second

sense it is true of many wrought irons. The cross-section of a fibrous structure, as Dr. Adolf Schmidt has pointed out, may be homogeneous. What is meant by the committee's preamble is the absence of fibrous structure or the presence of granular structure. Hence the preamble is defective, in defining as a characteristic of steel a property which it does not strictly possess at all, and which in the sense intended, even, not all steel possesses. I merely make this criticism by way of putting it on record, and explaining why I have taken pains to frame the resolution which I shall offer in such a way as not to indorse the preamble.

MR. WM. METCALF.—With regard to Mr. Howe's questions put to machinists and carpenters, I would say that the evidence of such men has no value whatever when it is known, as all steel-makers know, that many mechanics who have been steel-workers for years do not know what steel is, so far as its structure, or laws of action, or its composition is concerned. This whole discussion grew out of a mistake in the omission of a word. If Mr. Holley had said "cast" steel is "malleable iron made homogeneous by fluidity," and subsequently if I had said, in my paper before the American Society of Civil Engineers, "cast" steel "is iron which has been produced by fusion and which may be forged," this discussion probably would not have arisen. The question has three aspects: 1. The scientific; 2. The practical; 3. The commercial. I can appreciate the advantages in the proposed nomenclature, but do not admit its superiority to the one now in use, which may be tabulated as follows:

- Iron
  - Wrought
    - Bloom
      - Catalan.
      - Finery.
    - Puddled
      - Bars.
      - Plates.
      - Beams, etc.
    - Steel
      - Blister.
      - German.
      - Shear.
      - Puddled.
  - Cast
    - Not malleable
      - Pig Iron.
      - All ordinary castings.
    - Malleable
      - Castings—annealed and decarbonized in oxides.
      - Steel.
        - Castings—not highly carbonized.
        - Crucible.
        - Bessemer, or pneumatic.
        - Open hearth,
          - Or Siemens-Martin.
          - And Siemens by pig and ore process.

The above arrangement contains nothing more than the present

well-understood commercial classification, except the grouping of the old steels under the generic term "wrought steels." The advantage of having a new nomenclature, which can be literally translated from one language to another, is entirely outweighed by the coinage of the adjective "weld," and by the introduction of new terms which are no improvement upon those in use and which must lead to confusion. The word "weld," as here used, is entirely new, and not as good as "welded" would have been; and the good old word "wrought," which expresses something and means what it is intended to express, is much better than either. The existing commercial classification, which I have placed upon the board for convenient reference, and not as anything I propose or anything new, is entirely satisfactory to manufacturers and consumers, and is, I claim, also scientific.

The commercial side is important. People who know what they want order steel without any confusion of ideas. They order, for instance, steel that will not harden under any conditions, which may be cupped cold by being forced through a die, and from that through all of the quantities of carbon up to 0.30 per cent., giving such a variety of conditions as to bring every possible percentage of carbon into practical use, and the steel-maker meets these requirements without difficulty.

In answer to the statement that the term steel is applied to what the committee wish to call "ingot iron," for the purpose of giving it an enhanced and fictitious value, I would ask the gentlemen to make their researches among the skilled mechanics throughout New England, and even here in New York, wherever fine work is done; for instance, at sewing machine manufactories, silver-plating and nickel-plating works, etc., where steel has come into very large use. Among such people they will find that steel is ordered expressly on account of its superiority to iron—the difference being well understood—and that they gladly pay the increased price because it is compensated for in the labor required to secure a fine finish, and again in the enhanced value of their wares. The fact is, that in the last fifteen years this branch of the steel manufacture has grown to such an extent that a very large percentage, probably half the weight of all that is produced, is of this very mild steel; and it is not known that any one ever confused it with wrought iron or was deceived as to its value.

The object of my paper last fall was to show that this commercial

classification was not unscientific, and that it was perfectly clear and allowed no room for lawsuits. The classification of the International Committee introduces new terms, and with these terms confusion, which will open the door for all sorts of legal disputes, and as a scientific nomenclature it is no better than that which we have.

I agree with Dr. Raymond in his criticism of the word homogeneous so far as it meant to convey an impression of absolute homogeneity, for we can find a great variety of structure in the same bar of steel; but so far as it conveys the idea of such homogeneity of structure and of composition as are due to fusion it is correct. I would ask Dr. Raymond to insert in his resolution that the ingot steel and ingot iron of the new nomenclature are equivalent to what is now known as cast steel, including the so-called low steels, this being important commercially, because it is simply impossible to draw an arbitrary line between steels which will harden and steels which will not harden. Iron and steel cannot be separated by the property of hardening, for hardening depends on many conditions, the amount of carbon being only one. The state of the piece, the temperature to which the bar is raised, the temperature and conducting power of the cooling medium, and many other circumstances, influence the hardening. It being understood that the nomenclature on the board *is the correct existing commercial nomenclature,* and is so recognized by the Institute, there is no objection to the amended resolution, as it gives opportunity to those who wish to write in terms which shall be the same as those that are now adopted in Europe; and with this understanding I shall not oppose the use of the terms ingot iron and ingot steel for literary purposes.

PROF. T. EGLESTON: I have no authority to speak for the International Committee, and had intended to take no part in this discussion. I do so only because I think the work of the committee is not thoroughly understood. It would not have been possible to make any report against which there would not have been objections. Our profession makes, as a general thing, conservative men, and the first objection that would naturally arise to any proposed classification would be that it is new. The object of the committee was to present a classification which would be based upon some recognized principle, and which would not do away with any of the old terms with which we have been so long familiar, but which would classify them in some such way as, while retaining their use, to show exactly what

their relative meanings were, and thus prevent the confusion which now prevails. It was the intention at the outset not to introduce any new terms at all, and it may be said that this has been carried out, except so far as the English language is concerned. It is very remarkable that the words which have been selected can be exactly translated into three different languages, and that no serious objection has been urged to any of them except in this country. They have been accepted, almost without criticism, in Europe, and, what is most remarkable, in Germany, where there has been up to now such a multitude of terms in use. I could have wished that the English terms had been a little more English. The terms *weld iron* and *weld steel*, though they express the idea perfectly, sound strangely to Anglo-Saxon ears, while their equivalent terms are perfectly satisfactory, and have already been accepted. Personally, I should much rather prefer some other adjective to "weld" as applied to iron and steel, for, while it is thoroughly Saxon, it is not Anglo-Saxon. I think it possible that some other term might be found that would express the idea of the mode of manufacture as this does, and at the same time be more English. The objection to the term as it now stands is one of usage, which, if it is adopted, use will correct, but I see no objection whatever to the principle involved. It does not mean that the material so classified possesses the property of welding, for if that was the meaning it would give no proper distinction, since in the strict sense of the term even cast iron may be welded; but it means that the particles have been welded together in the process of manufacture by pressure and not welded by fusion, as is the case with cast iron, ingot iron, and steel. The ambiguity of the term is not a serious objection to it, and comes only from the fact that the report of the committee is necessarily concise. The report would have been by far too long if it had been thought necessary to go into the discussion of all the reasons which led to its adoption by the committee. I should prefer that some other word should be found, if it is possible, but it seems to me doubtful whether any other term can be found which can be translated, and which will express the idea of the mode of manufacture as this does, and I therefore hope that the finding of another term may be referred to the committee. I should be exceedingly sorry to have an attempt made to modify the report without the most careful deliberation, and think that, if it is to be modified, the modification should be made by the same persons who presented the report. If no other word can be found which will express the

idea in the three languages, I should prefer the report to remain as it is rather than to sacrifice any principle which is expressed in it. I am unable to see why the manufacturers should make any objection to the classification, since no change has been made in the definitions which involve any new principle. The terms "*cast*" iron, "*cast*" steel, and "*pig*" metal were considered to be just as objectionable at the time they were introduced as the terms proposed, and the term pig, though it has a history, is a very arbitrary selection. Long usage has made us familiar with them, but if we should undertake to criticize the accepted terms of metallurgy, what should we do with the gobs, the sows, the bears, and other similar terms that we find accepted everywhere without criticism? Usage has made us familiar with them, and usage will make us equally familiar in a much less time and with much greater reason with the terms *weld iron* and *weld steel*.

The matter at stake in this discussion is the principle involved more than the terms. Iron and steel will always remain iron and steel, even though the modes of manufacture may change; but, with the progress of invention and discovery, different qualities of the material will be brought into prominence, which will give names more or less definite to the material manufactured. These will involve new considerations possibly, and when these considerations are brought forward we shall probably have to modify the names again just as they have been modified little by little in years gone by, and brought us into the confusion in which we now are. With the active research of to-day, and the necessity of reducing the cost of manufacture, new relations of the materials composing iron and steel will be given, some of which may be only trademarks, just as to-day we have carbon, titanium, chromium, silicon, and other steels. These names will involve more or less truth, and will come to the surface and will disappear from time to time, and will simply arrange themselves in their proper places under the new classification, but that will not affect it. It has been recently discovered that phosphorus and silicon have a most unexpected influence in preventing the solubility of cast iron, so that recent investigations seem to show that, if we can only get certain proportions of phosphorus and certain proportions of silicon in the iron, and be able to cast it thin enough, we may be able to dissolve gold and platinum in vessels of this character. The development of such a manufacture may lead to some other important discoveries, and the product may receive a name

which will be current, but it will not necessitate any such change in the classification. Much has been said in regard to retaining the term of *cast steel*, which twenty years ago was a very precise term, but has become so ambiguous that we require already the use of another adjective, as "crucible" cast steel, in order to define it. It is not the intention to do away even with this term for commercial purposes, but it does not seem to me at all improbable that twenty years hence we shall neither have the term *cast steel* nor even *carbon steel* in use, but that we may possibly find that other substances combining in certain proportions with iron will produce a material which will have the properties of steel, and yet not be steel according to our present ideas. I must agree with Mr. Howe that, from the time of Tubal Cain down, hardening and tempering have been characteristic properties of steel, and it has not been forgotten in the report, but it would have been unwise to have taken these properties only as a distinguishing feature of the commercial compound of carbon. It must be remembered that the report of the committee was a compromise, but it was of such a nature that no principle was sacrificed in making it, which is, I think, the reason why the very acute and very critical German minds have adopted it. It was adopted by the committee more to have a common language in technical discussion which would make the research of one country available in another, and do away with the ambiguity of the terms now in use rather than for commercial purposes; but while the report is fully adapted for scientific discussion, it seems to me equally well adapted to settle the vexed questions which are constantly arising in commercial transactions, and has, besides, the very great merit of being susceptible of accurate definition, and capable of being applied equally well to commercial and scientific transactions. I hope, not as a member of the committee, but as an engineer, that the report will be adopted, and that, if any changes are to be made in it, the part of the report in which change seems to be desirable shall be referred to the committee for their consideration. The report, as a whole, has been hailed in Europe as a harbinger of peace, and familiarity with it will, I think, do away with most, if not all, of the objections raised against it.

THE GODERICH SALT REGION.

BY T. STERRY HUNT, LL.D., F.R.S.

THE deposit of rock-salt which is known to exist along the eastern shore of Lake Huron, in the province of Ontario, has lately been more completely explored than before, by a boring with a diamond drill, put down by Henry Attrill, Esq., of New York City, and the results obtained are so important in every way that I make no apology for presenting them to the Institute of Mining Engineers. I may be permitted to preface an account of this remarkable exploration, and of its results, with a historical sketch of the discovery and development of this salt-region.

It was in December, 1865, that a boring was begun near the town of Goderich, in the hope of finding petroleum. In this the adventurers were disappointed, but, after passing through about 800 feet of limestone, they encountered a series of variegated marls, in which, at a depth of 964 feet from the surface, a bed of rock-salt, 30 feet in thickness, was met with in May, 1866. The boring was carried to a depth of 1010 feet, ending in hard rock, and yielded, by pumping, a very pure saturated brine when examined by me in August of the same year. In the report of the Geological Survey of Canada for 1863–66, published early in 1867, I described this salt-well, with many geological details, and gave an analysis of the brine.

In the next three years a considerable number of wells was sunk in and around Goderich, and numerous trials were made in various other parts of the region. Salt was found at Kincardine, thirty miles north-northeast from Goderich, at a depth of about 900 feet, and also at Clinton, thirteen miles southeast, at 1180 feet. Records of these wells, with analyses of the brine from them, were given by myself in a subsequent report of the Geological Survey, 1866–69, published in 1870 (pp. 211–244), together with accounts of various unsuccessful borings in the neighborhood, analyses of the brines from the various wells (including one analysis by Dr. Goessmann), with many details of the salt-manufacture at Goderich, at Syracuse, New York, and at Saginaw, Michigan. The geological character of the region was there discussed at length, and it was shown that the salt here occurs in the Onondaga or Salina formation, which

is also the source of the Syracuse, though not of the Saginaw, brines.

Since that date some farther discoveries have been made in this region. At Kingstone's Mills, in Warwick, about fifty miles a little west of south from Goderich, a boring, begun for oil, in the black shale at the summit of the Hamilton formation, was carried down 1200 feet, when salt was met with. This was found, alternating with marls and harder beds, for 130 feet, beneath which 70 feet of hard rock were penetrated, making 1400 feet in all. From this well a very pure and saturated brine was raised, which was analyzed by me, and the boring described, in 1870.

The observations from that date to the end of 1874 are to be found in the report of Mr. J. Lionel Smith to the director of the Geological Survey of Canada, dated November, 1874, and published in 1876. Rock-salt had been found at Port Frank in Bosanquet, a little to the north of Warwick, and also, at a depth of 1100 feet, in an oil-well in the township of Dawn, south of Enniskillen. Another well had been sunk at Kincardine to a depth of 1007 feet (being 110 feet below the previous boring), from which it appeared that beneath 12 feet of rock-salt, and 36 feet of alternating marls and salt, was another bed of 60 feet of pure salt. Similar results had been obtained at Goderich, where, in the International well, were found, in descending order—salt, 19 feet; rock, 30 feet; salt, 24 feet; rock, 3½ feet; salt, 32 feet; rock, 8 feet; the boring ending at 1175½ feet. Besides the wells at Kincardine, Goderich, and Clinton, salt had also been met with at Seaforth, about thirty miles southeast of Goderich, where it was found at 1035 feet. The boring was carried 100 feet farther, and, according to Mr. Smith, a third layer of salt was reached here, as at Goderich. At Carronbrook, five miles farther to the southeast, a well sunk 1396 feet showed no salt, and at Mitchell, eleven miles southeast from Seaforth, a boring was carried down 2008 feet. No salt was there met with, and after passing through the Salina marls, and the underlying Guelph and Niagara limestones, the boring was carried 300 feet in the red shales of the Medina formation.

At Inverhuron, on the lake shore, nine miles north of Kincardine, marls but slightly impregnated with salt were met with at 895 feet, and the boring was abandoned in hard limestone at 1007 feet. At Teeswater, some twenty miles farther to the eastward, a well was bored to 1180 feet, traversing somewhat saliferous strata, but no rock-salt; and similar negative results were obtained by a boring of 1200 feet at Ainsleyville, about fifteen miles north of Seaforth. These

observations serve to show the limit, to the north and east, of the salt-deposit. It occupies but a small area in the great extent of the Salina formation, which underlies and bounds on two sides the shallow basin of Corniferous limestone, through which the borings of Teeswater, Ainsleyville, and Mitchell have been sunk. To the southward, however, the same salt-deposit, or perhaps a distinct one, would appear to have a considerable extension.

In 1873 Mr. J. Gibson published in the *American Journal of Science* an account of this salt-region, which he subsequently embodied in a communication to a Committee of the Canadian House of Commons in 1876. His account is little more than an unacknowledged compilation from my official report of 1869, together with records from the borings of some of the newer wells just mentioned, and some curious errors on the part of its writer.

The brines obtained from the various wells of Goderich, Clinton, Seaforth, and Kincardine are, as appear from my published analyses, of great strength, varying from 90° to 100° of the salometer (the latter degree indicating saturation), and hold a much smaller proportion of earthy chlorides than those of either Saginaw or Syracuse. The manufacture of salt by artificial heat is carried on at all these Canadian wells, and in 1873, according to the data obtained by Mr. Smith, the production from them was over two and one-third million bushels, of which very nearly one-half was sent to the United States, notwithstanding an import-duty of 34 cents per barrel, and 8 cents per 100 pounds of salt in bulk; making $1.60 per ton of 2000 pounds, or very nearly 4½ cents for the bushel, estimated at fifty-six pounds.

The Canadian demand for salt is limited, while that of the United States is large and rapidly increasing. This country imports large quantities of salt from the West Indies, Southern Europe, and Great Britain, the latter country sending us 6,000,000 bushels in 1872. The interior States are, however, in great part supplied from local sources. The total salt-production of the country, according to the census of 1870, was equal to 17,606,105 bushels, of which 17,063,-405 bushels were made from the brines of New York, Michigan, Ohio, Pennsylvania, and West Virginia. I have not the amount of salt imported in 1870, but for the fiscal year 1868–69 it is set down at 19,331,591, and in 1874–75 at 26,885,948 bushels. The salt-production of New York reached its highest point in 1870, when it was 8,748,115 bushels, since which time it has fallen off, and was only 5,392,677 bushels in 1876. Michigan, on the other

hand, which, according to the census, produced only 3,981,316 bushels in 1870, attained 7,313,645 bushels in 1876.

Impressed with the great future offered by the interior salt-market of the United States, Mr. Attrill resolved to ascertain whether this vast deposit of rock-salt in the Goderich region was of a nature to be advantageously extracted by mining. Having acquired a large tract of land on the lake shore, commanding the port of Goderich, and affording the necessary facilities for shipment, he proceeded, by the aid of a diamond drill, to determine the nature of the salt-beds beneath. This work was begun and successfully completed in the course of the year 1876. Previous to its completion, however, in September last, Mr. Attrill consulted me professionally in the matter, and placed in my hands the whole of the results of the operation for study, analysis, and description. The principal results of my inquiries were embodied by me in a letter published in the *Globe*, of Toronto, on the 9th of January, 1877, and I am now indebted to the generous courtesy of Mr. Attrill for permission to lay the details of the whole operation, and the results of my studies, before the Institute of Mining Engineers.

Having previously been furnished with a copy of the record or log of the well, I received on the 14th of November a selection from the cores extracted, to the depth of 1295 feet, and, on the 16th of December, those from the continuation of the boring, down to the point at which it was abandoned, 1517 feet from the surface. The cores were sent me from Goderich to Boston, and on each occasion I was visited by Mr. W. S. Fritz, of Pottsville, Pennsylvania, the very intelligent and skilful foreman of the drilling, who carefully went over the collection of cores with me, and gave many verbal explanations, besides leaving with me the diary of the operations from the beginning. The work was commenced at Goderich, on the 10th of March, 1876, by sinking a well through gravel and clay, to a depth of 35 feet, after which a wrought-iron pipe was driven 10 feet farther. The annular diamond drill was then used for about 10 feet more, passing through what is described as "a broken sandy rock," yielding but a few inches of core. Below this a gravel bed was reached, through which iron pipe was again driven to a depth of 59 feet. Drilling was once more resorted to, and, after passing through what seemed to be boulders or loose masses of limestone, to a depth of 72 feet, a stratum of sand and gravel, with some clay, was reached, through which iron pipe was again driven until, at a depth of $78\frac{9}{12}$ths feet, what was regarded as the bed-rock

was reached, on the 15th of April. The record up to this point is as follows:

	Feet.	In.
Gravel,	14	0
Blue clay,	31	0
Loose stones, or boulders,	10	0
Gravel,	4	0
Loose stones, as before,	13	0
Sand and clay,	6	9
Total of superficial deposits,	78	9

For the next 15 feet boring was effected partly by a steel drill and partly by the diamond drill, passing through what was described as a porous limestone. From this portion only two feet of core were obtained. Beyond this the drilling proceeded regularly, with an annular diamond drill of two and a half inches diameter, up to July 10th, when a depth of 349 feet had been reached. From the 270 feet of solid rock thus bored only 103 feet of cores were extracted. At this point the work was interrupted from the loss of tools in the bore-hole. It was, however, resumed on the 20th July, this time under the direction of Mr. W. S. Fritz, who, after extracting the tools, recommenced the boring on the 10th of August. An influx of water was perceived, it is said, at 135 feet, and another and more considerable one having been met with at about 360 feet, an iron pipe of $2\frac{3}{8}$ inches was driven down to a depth of 365 feet, thus excluding the water.

Below this point the boring was made with a two-inch annular diamond drill, and was carried on without any interruption (except the loss of a week from the breaking of a drum of the lifting-machinery) up to the 6th of December, when the work was stopped at a depth of 1517 feet from the surface, making a distance of little over 1438 feet drilled in the solid rock.

Up to 349 feet, we have seen that the cores preserved measured only 103 feet, but for the succeeding 936, or to a depth of 1295 feet, reached on the 10th November, there were extracted $853\frac{7}{12}$ths feet of cores. From this point to the bottom, a distance of 222 feet, there were obtained, according to the record, only 98 feet of cores, which were in an exceedingly soft and crumbling state. Of this distance, the last 125 feet (below the lowest salt-bed) yielded only about 23 feet of cores; the average day's boring, of about ten feet, here giving, in many cases, only one or two feet of solid core, and in one instance none at all, the whole portion removed breaking up into a soft incoherent mud.

Of the cores down to the vicinity of the salt-bearing rock, or to 910 feet from the surface, I received only a selection of fragments from one to six inches in length, each duly labelled, and, in addition to these, portions of the clay, gravel, and boulders. I had, for the 830 feet of solid rock, ninety-three specimens, measuring in all about thirty feet, judiciously chosen with a view to give examples of every variety of rock met with in this part of the boring. Below 910 feet the whole of the cores extracted, amounting, for the 617 feet penetrated, to 443 feet in length, were sent me, arranged and labelled, in twelve boxes. These materials were, at the request of Mr. Attrill, submitted to a careful chemical and mineralogical investigation, in order to determine whatever might be either of economic or scientific importance. The results of the examinations already made are embodied in the present communication.

The salt-bearing strata at Goderich, as will be shown in the sequel, are nearly horizontal, so that the measurements given below may be taken as representing the actual thickness of the beds traversed. The entire rock-section, as shown in the cores from the boring, may be conveniently described in seventeen divisions, as follows:

Boring, by Mr. Attrill, at Goderich, Ontario.

		Feet.	In.	Total Feet.	Total In.
I.	Clay, gravel, and boulders, ...	78	9	78	9
II.	Dolomite, with thin limestone layers, .	278	3	357	0
III.	Limestone, with corals, chert, and beds of dolomite, ...	276	0	633	0
IV.	Dolomite, with seams of gypsum, . .	243	0	876	0
V.	Variegated marls, with beds of dolomite,	121	0	997	0
VI.	Rock-salt, 1st bed, ...	30	11	1027	11
VII.	Dolomite, with marls towards the base,	32	1	1060	0
VIII.	Rock-salt, 2d bed, ...	25	4	1085	4
IX.	Dolomite, ...	6	10	1092	2
X.	Rock-salt, 3d bed, ...	34	10	1127	0
XI.	Marls, with dolomite and anhydrite, .	80	7	1207	7
XII.	Rock-salt, 4th bed, ...	15	5	1223	0
XIII.	Dolomite and anhydrite, ...	7	0	1230	0
XIV.	Rock-salt, 5th bed, ...	13	6	1243	6
XV.	Marls, soft, with anhydrite, ...	135	6	1379	0
XVI.	Rock-salt, 6th bed, ...	6	0	1385	0
XVII.	Marls, soft, with dolomite and anhydrite,	132	0	1517	0

With this it is interesting to compare the record of the International well, already noticed, drilled in the ordinary way, in the town of Goderich, one mile south from the above, and about 105 feet

over the level of the lake, Mr. Attrill's boring being about 22 feet over the same level. The top of the first bed of salt was found at 1064 feet, as compared with 997 feet above; and the thicknesses of the divisions penetrated below this were as follows: VI, 19 feet; VII, 30 feet; VIII, 24 feet; IX, 3 feet; X, 32 feet. These measurements of the total depth, and of the successive divisions, are, from the manner in which they are got, less certain than those obtained by boring with the diamond drill.

I now proceed to describe, in descending order, as numbered, the several divisions of the section. Passing over I, which consists of the superficial deposits already noticed, we come to

DIVISION II. This, extending from 78 feet 9 inches to 357 feet, consists almost wholly of dolomite or magnesian limestone, varying in color from pale-gray and buff to a dark-gray, passing into chocolate-brown. This latter color is due to a little bitumen, the odor of which is very marked in the specimens. These dolomites are in some parts fine-grained and compact, and in other parts coarsely granular and crystalline. In many beds the cut surface of the compact rock, as seen in the cores, is marked with numerous small, round, shallow pits, from one to two-tenths of an inch in diameter, apparently formed by the dissolving-out of some substance. These give the rock a worm-eaten aspect, which led the late Prof. Eaton to call similar beds, belonging to the same geological horizon in the State of New York, *vermicular lime-rock*. In other beds the surface of the cores is marked from the removal, by solution, of thin-bladed crystals, which has given rise to what appear like small gashes or incisions in the compact rock. These are sometimes half an inch in length, and occasionally intersect each other at right angles. Some portions of the rock are porous or cellular throughout, and in other parts the mass is made up of thin curved or waved laminæ, alternating of lighter and darker colors.

The compact vermicular rock was met with in several specimens from between 100 and 150 feet, that with thin-bladed crystals between 260 and 300 feet, and the finely laminated variety at 189 feet, while from this to 217 feet the specimens were coarsely granular, and often cellular. The chocolate-colored bituminous beds were at from 320 to 351 feet. These various rocks scarcely effervesced with an acid, unless previously crushed to powder, and were evidently proper dolomites. Layers of a more calcareous rock, effervescing like a true limestone, were, however, detected between 93 and 102 feet, and between 181 and 183 feet.

DIVISION III; from 357 to 633 feet. The separation of this from the divisions above and below was determined by the following reasons: The record of the boring between 351 and 357 feet gives "fossiliferous limestone," and two specimens of cores sent me from 357 and 360 feet, hold, imbedded in a gray dolomitic paste, small white calcareous masses, which are very probably organic, inasmuch as organic remains of recognizable forms are found abundantly in the next 170 feet. Again, flint or chert was noticed in the boring at 379 feet, and abounded not only throughout the fossiliferous portions, but as far as 633 feet; from which lower limit up to 428 feet it was described in the record as a hard white and opaque rock. Below the partially calcareous stratum, noticed at 360 feet, varieties of dolomite, compact, laminated, granular, and bituminous, resembling those found in Division II, were seen in six specimens to 374 feet, from between which point and 383 feet came two specimens of gray mottled cavernous limestone. Following these, were dolomites, sometimes with more or less calcareous admixtures, in six specimens, to 417 feet. In a specimen of gray crystalline dolomite from 402 feet were numerous cavities from two to five millimetres in diameter, left by the removal of stellate groups of bladed crystals. From between 417 and 428 feet were sent me two specimens of gray limestone, one holding a calcareous coral (*Favosites*), and another a similar coral silicified, together with a portion of chert. Below this, at 438 feet, was a layer of cellular dolomite with crystals of carbonate of lime, after which, from 444 to 500 feet, were six specimens of gray fine-grained limestone, in three of which were corals, as before, in one case silicified. Between 500 and 509 feet was a layer of fine-grained dolomite, and between the latter and 528 feet gray limestone with corals. From between this point and 535 feet came a finely granular laminated dolomite, having white chert above and below, in immediate contact with it; while from 547 to 594 feet were two specimens of gray limestone, with patches and layers of white chert.

In this last interval, the rock just above 535 feet 2 inches is described as rather hard, and from thence to 547 feet 7 inches, probably on account of the hardness of the rock, the drilling was effected by a solid bit. From this point to 557 feet 10 inches the annular drill was used, beyond which, to 573 feet 10 inches, the solid bit was again had recourse to. There is thus, in this part of the boring, a little over 28 feet from which no core was obtained. Between 594 and 633 feet were two specimens of dolomite, finely laminated and including chert, while the last portion, from 633 feet, was from a bed

of white opaque chert or flint, said by the foreman to be the lower limit of this rock.

Division IV; from 633 to 876 feet. Of this division, the lower limit of which was marked by the marls of V, I had twenty-six specimens, all of which were dolomites, varying in color from buff to light and dark gray. In texture they were finely or coarsely granular, or compact, and often thinly laminated. Near 726 and 745 feet, and again near 840 feet, were seen casts of thin-bladed crystals, like those noticed in Division II, which were either vertical or oblique to the stratification. In four specimens, from 726 to 803 feet, thin layers of gypsum, never more than half an inch in thickness, were interstratified in the dolomites. No mention is made of gypsum in the record of the boring, but it is probable that an inspection of the whole of the cores from this division might show more of this substance. From 780 to 834 feet the record describes the rock as intermixed with slate, none of which appears in the specimens sent me.

Division V; from 876 to 997 feet. Of this division, the lower limit of which is the top of the first bed of rock-salt, the first 66 feet, or to 940 feet, are described in the record as "fire-clay slate," from their resemblance in texture to strata with which the borer had been familiar in the coal-regions of Pennsylvania. From 894 feet the rock is said to have been salt to the taste, and below 940 feet crusts of salt formed on the cores in drying; so that this lower portion of the division is described in the record as "salt rock," with the exception of some harder layers, designated as "limestone." Of the first 34 feet I received four specimens, which are clayey rocks, best described as variegated marls. They are bluish-gray, dark-red, greenish, and nearly white, the colors being banded and mottled in their arrangement. Below 910 feet the whole of the cores were sent to me; they consist of marls, as before, including, at 922 feet, a layer of 1 foot 6 inches of granular dolomite. Below this, much of the marl was of a dark reddish-brown, and inclosed, to the base of the division, numerous beds of dolomite, which were porous or compact in texture, and often banded.

These marls are apparently intimate mixtures of clay with dolomite, and when tried, in a great many cases, with warm chlorhydric acid, never failed to effervesce freely. Similar rocks from the same geological horizon, near Brantford in Ontario, were examined by me many years since. One of them, a green crumbling marl, contained 45 per cent., and another, darker and more compact, 75 per cent. of

dolomite; the remainder, in both cases, being a clay. Some of these dolomitic marls are well adapted to the manufacture of hydraulic cements. (See *Geology of Canada*, 1863, pages 625 and 807.)

DIVISION VI, from 897 feet to 1027 feet 11 inches; being the first bed of rock-salt. Until reaching this the drill had been supplied with water, which was now replaced by a brine, made fully saturated for the purpose, by the use of which the solution of the salt in the boring was prevented, and cores of it were obtained. The first 2½ feet of this division were, however, extracted while fresh water was still employed, and showed a solid gray finely granular dolomite, from which masses of rock-salt, presenting no regular forms, and amounting perhaps to one-third of the bulk, had been dissolved. To this succeeded 7 feet 11 inches of salt, holding a small proportion of earthy matter, and including layers of dolomite; then 3 feet 9 inches of porous dolomite, with some marl, holding irregular masses of salt, as before, and finally 16 feet 9 inches of salt, in parts colorless and transparent, and in part stained by earthy impurities, and including layers of fine-grained dolomite; the whole making for this division, composed chiefly of rock-salt, a thickness of 30 feet 11 inches. This stratum, as displayed in the boring, is not pure enough for mining.

DIVISION VII; from 1027 feet 11 inches to 1060 feet. The upper four feet of this division consist of a gray dolomite, often finely laminated, with disseminated masses of salt, followed by a gray porous dolomite, holding salt in frequent veins or transverse seams, to 1052 feet. The remaining eight feet of the division consist of a marl, resembling those described above.

DIVISION VIII; from 1060 to 1085⅓ feet. This, the second bed of rock-salt, has, at the top, 9 inches of perfectly colorless and transparent salt, to which succeed 6 feet 9 inches of salt mixed with some rocky matter; then 7 feet 1 inch of salt with very little stain or discoloration, followed by 10 feet 9 inches of pure white crystalline salt, inclosing a layer of dolomite 1 inch in thickness, near the base. The whole of this division, measuring 25 feet 4 inches, is fit for mining, and in some parts, as will be shown, is of remarkable purity.

DIVISION IX; from 1085 feet 4 inches to 1092 feet 2 inches. This bed, of 6 feet 2 inches, consists of dolomite, holding salt both in interstratified layers and in thin vertical seams.

DIVISION X, from 1092 feet 2 inches to 1127 feet, makes the third bed of rock-salt, 34 feet 10 inches in thickness, and consists throughout of solid salt, with a very small proportion of impurities, which

give it a slight shade of color. With a little sorting it might probably be used for all ordinary purposes. It should here be remarked that of the lower 5 feet 5 inches of core from this bed, only about one-half was received.

DIVISION XI; from 1127 feet to 1207 feet 7 inches. This portion, of 80 feet 7 inches, consists, for the first 43 feet, of gray marls, inclosing much red salt in layers and in vertical veins, and including, moreover, numerous thin dolomitic beds. Below 1170 feet there is found, for a distance of 4 feet, granular dolomite, with several layers of grayish-white translucent anhydrite, each about an inch in thickness, followed by porous dolomite beds, with some marls, the whole inclosing vertical veins of rock-salt, which are reddish in color and fibrous in structure, the fibres being transverse to the sides of the veins.

DIVISION XII; from 1207 feet 7 inches to 1223 feet. This is the fourth bed of rock-salt, from which, as appears from the record, only the upper two feet, and the lower two feet nine inches, of cores were preserved. Of these the former was somewhat impure, and the latter was a white salt, including thin layers of dolomite.

DIVISION XIII; from 1223 to 1230 feet. This division of seven feet consists, at the top, of one foot of porous dolomite, followed by two feet of granular anhydrite, holding irregular masses and grains of salt, beneath which are four feet of dolomite and marl.

The anhydrite, or anhydrous sulphate of lime, from this division resembled closely that found in Divisions XI, XV, and XVII. It was finely granular, crystalline, very tough, bluish-gray in color, and subtranslucent. A specimen free from included salt had a specific gravity of 2.90, and lost by ignition only .62 per cent. of its weight.*

DIVISION XIV; from 1230 to 1243½ feet, is the fifth bed of rock-salt, measuring 13½ feet. Of this core, by an accident, the greater part was dissolved in the bore-hole, but 5½ feet, from above 1241 feet, are preserved, and are impure salt, though clear and white in portions.

DIVISION XV; from 1243½ to 1379 feet. From this division of

* This anhydrite, when placed in fresh water or in saturated brine, at ordinary temperatures, gradually becomes hydrated, from the surface inward, and changes into gypsum. It is worthy of inquiry whether the mechanical effect of great pressure may not serve to explain the existence of anhydrous rather than hydrated sulphate of lime in deepseated deposits, and the conversion of the latter into anhydrite.

$135\frac{1}{2}$ feet, only $109\frac{1}{3}$ feet of cores were preserved. They consisted of red, bluish, and greenish marls, banded and variegated, holding, throughout, layers of reddish salt of from a few inches to a foot, and at about 1300 feet, from one to two feet in thickness. Below this are several thin layers of bluish anhydrite, followed by soft exfoliating marls, chiefly reddish in color. No beds of hard dolomite were found in this division.

DIVISION XVI; from 1379 to 1385 feet. This, which is the sixth bed of rock-salt, measures six feet, and is pure white and translucent.

DIVISION XVII; from 1385 to 1517 feet. This division, extending to the bottom of the boring, was exceedingly soft, so that, from the 132 feet, only 28 feet 3 inches of cores were preserved. At the top were six feet of porous dolomite, holding layers of from two to four inches of bluish anhydrite. The portions preserved from below this consisted of soft exfoliating variegated marls, chiefly greenish and grayish in color. The ten feet at the base, however, consisted of a dark gray dolomitic rock, somewhat harder, but crumbling, and exhibited cavities from the dissolving-out of salt. These lower portions also included thin layers of anhydrite. The boring at this point was abandoned, because it was considered that no practical good results were to be expected from its continuance.

The above-described section shows, in the 520 feet of strata below the top of the first salt-bed, six layers of rock-salt, measuring in all 126 feet, without counting the considerable amount of salt present in thin layers, and in veins, throughout the rocks.

These beds of rock-salt, as we have seen, are not alike in purity. The first is scarcely suitable for mining, while the second is remarkably pure, and the third approaches it in this respect. The latter two beds, which measure together over 60 feet, are separated from each other by a layer of less than seven feet of rock, and for practical purposes may be regarded as one great workable mass of rock-salt. It was desirable to determine the composition of this salt, and especially of the purely white and translucent portion of the second bed (Division VIII), measuring, as has been shown above, $10\frac{2}{3}$ feet. The quality of this portion, as seen in the cores, was apparently uniform, but in order to insure an average of the mass, portions of equal size were broken from each foot of the core, and the ten specimens thus got were crushed up together, to get a sample for analysis. This was chemically examined under my supervision, by Mr. Gould, the determinations being made in duplicate, and found to agree very

closely. The results were as follows, the chloride of sodium being determined by difference:

Chloride of sodium,	99.687
Chloride of calcium,	.032
Chloride of magnesium,	.095
Sulphate of lime,	.090
Insoluble in water,	.017
Moisture,	.079
	100 000

From the above analysis it appears that, deducting the adherent moisture, the amount of foreign matters in this salt is 0.234, or less than a quarter of one per cent. Its remarkable purity will appear when this result is compared with the analyses of the best commercial salts, the impurities of which are essentially of the same kind. In the case of the rock-salt of Cheshire, in England, I copy from a report printed by the British House of Commons, in 1873, an analysis of "Crushed Marston rock-salt," made by Dr. Crace Calvert for Messrs. Fletcher & Rigby, as follows: Chloride of sodium, 96.70; chloride of calcium, .68; chlorides of magnesium and potassium, traces; sulphate of lime, .25; insoluble matters, 1.74; moisture, .63 = 100.00. This gives of foreign matters, deducting the moisture, 2.67 per cent., or more than eleven times as much as the Goderich rock-salt. Another analysis of Cheshire rock-salt, cited by Watts in his *Dictionary of Chemistry*, gives 1.70 per cent., and one of the famous rock-salt of Cardona, in Spain, 1.45 per cent. of foreign matters.

The salts got by evaporation from sea-water and from brines, with which our markets are in great part supplied, contain nearly as much impurity. From data gathered by me, and published some years since in a report of the Geological Survey of Canada, already referred to, it appears that the amount of foreign matters in Turk's Island salt is 2.34; in Saginaw salt, 2.00, in Syracuse solar salt, 1.15; and in the boiled salt from the same locality about 1.50 per cent. Of the salt made at Goderich from the brines pumped from the salt-bearing strata of the region, three samples, analyzed by me in 1871, gave for coarsely crystalline salt, 1.097; flaky medium salt, 1.282; and fine salt, 1.625 per cent. of foreign impurities. The fine salt, which is the least pure, is made by boiling, the others by slower evaporation. The analysis by Dr. Goessmann of another sample of Goderich boiled salt gave 1.50; while the rock-salt from the layer

of 10¾ feet in Division VIII of the section, as we have seen, contains only 0.234 per cent., or less than one-sixth of the amount of foreign matter found in the boiled salt made from the Goderich brines.

A considerable portion of the impurities in the commercial salts which we have thus compared with the Goderich rock-salt, consists, it is true, of sulphate of lime (gypsum), which is not actively injurious; but the brines of Saginaw and Syracuse, and, to a less extent, those of Goderich, contain (as I have shown at length in the report of 1869, already quoted), chlorides of calcium and magnesium, which, in the ordinary methods of salt-making, accumulate in the pans or kettles, and give to the salt very objectionable qualities, unless they are removed by chemical processes, as is done in the superior quality of dairy-salt made at Syracuse.

The less pure salt, which overlies the pure white layer in the second bed, was examined, like the preceding, by taking small portions from each foot of the core, and making from them an average sample. It was analyzed, as before, with the following results: chloride of sodium, 91.24; chloride of calcium, .57; chloride of magnesium, .05; sulphate of lime, 2.81; insoluble in water, 5.33 = 100.00. The impurities, consisting of gypsum and marl, are very irregularly distributed through the layers; and it would appear from an inspection of the cores, that by a proper selection it would be easy to get a large proportion of salt much purer than this, and probably equal to the Cheshire salt of which the analysis has been given above. The same is true of the greater part of the third bed (Division X). These great masses above and below the white salt would yield, in abundance, salt for agricultural and manufacturing purposes, and probably for the salting of provisions; while the layer of pure white salt, when ground, would give a product which for the dairy, and for table use, would be unequalled in purity and in beauty.

The saliferous strata of Stassfurth and Douglashall, in Germany, and of some other regions, contain, as is well known, soluble salts of magnesia and of potash, which, in the localities named, have been found of great economic importance. A careful examination of the cores from the Goderich boring was accordingly made, in order to determine in these the presence or absence of such compounds. Samples were taken not only of the solid salt of the various salt-beds, but of that found in veins and thin layers, or disseminated throughout the saliferous strata. The following is a description of these samples from the various divisions of the section:

Division V; marls; saline efflorescence on the core, from 983 feet.

Division VI; first bed of salt; glassy salt, 1000 feet; granular salt, 1026½ feet.

Division VII; dolomite and marl; white granular salt in vein, 1031 feet; red fibrous, at 1057 feet.

Division VIII; second bed of salt; dark-colored glassy salt, 1085 feet.

Division X; third bed of salt; white glassy, 1092½ feet; white opaque, 1095 feet; white transparent, 1100 feet; white, with marl, 1116½ feet; reddish, 1121 feet.

Division XI; marls, etc.; reddish salt in marl, 1127 feet; reddish, irregular lumps in marl, 1134 feet; white granular in marl, 1142 feet; white, like the last, 1152 feet; white, vertical vein in dolomite, 1178 feet; small grains in dark porous dolomite, 1180 feet; grains, like the last, 1183 feet; thin layers of dark-brown salt in porous dolomite, 1192 feet; reddish salt in vertical seams in dolomite, 1201 feet; reddish salt, as before, 1205 feet.

Division XII; fourth bed of rock-salt; colorless and transparent salt, 1208 feet.

Division XV; marls; red granular salt, 1272 feet; red granular salt, 1283 feet; red fibrous salt, 1294 feet; red fibrous salt, 1314 feet.

Division XVI; marls; granular salt with anhydrite, 1420 feet; white glassy, 1500 feet; brine from 1500 feet.

Of each of these specimens, twenty-eight in number (without counting the brine from the bottom), there was taken a gramme or more, which was dissolved in a little water and examined for potassium, by the addition of platinum-chloride and alcohol, but in no case was there found an appreciable quantity of potash-salt, the soluble material being in every instance nearly pure chloride of sodium. The brine from 1500 feet, tested in like manner, contained only traces of potash-salt, with small portions of the chlorides of calcium and magnesium.

In calculating the results of mining rock-salt it is necessary to know its specific gravity, and upon this point there are found great discrepancies, the determinations by different observers worthy of confidence, varying from about 2.00 to over 2.25, so that Prof. Henry Wurtz has been led, from a comparison of a great number of observations, to conclude that these differences correspond to different degrees of chemical condensation. In the present case I sought to fix, with as great care as possible, the specific gravity of selected specimens of pure rock-salt from the white layers of the second bed

(Division VIII) of the section. For this purpose freshly distilled oil of turpentine, having a specific gravity of 0.863, was used, and the determinations were made at 15° C. Two fragments of the transparent colorless salt, weighing respectively a little over four, and ten and a half grammes, gave each a specific gravity of 2.172 ; a third fragment of about ten grammes, 2.168 ; and a fourth of nearly five grammes, 2.133. This last was imperfectly transparent, and was seen, under a small magnifying power, to contain numerous little cavities filled with brine, to which its lower specific gravity is to be ascribed. We may, I think, accept 2.172 as the density of the pure pellucid rock-salt of this bed; but for the purposes of calculation in mining, the lowest figure, or more conveniently 2.125, being two and one-eighth times the weight of water, may be safely assumed for the great mass of salt.

A layer of rock-salt, one foot in thickness, with a specific gravity of 2.125, will contain for each acre of superficies (4840 square yards) 2873 tons of 2000 pounds, or 2582 gross tons of 2240 pounds; which gives for the layer of white salt 10¾ feet thick, 27,751 gross tons, equal to 1,110,280 bushels (estimated at 56 pounds each) to the acre. As regards the loss in mining, from pillars left behind, etc., the average in coal-mining in England is estimated at twenty per cent., and as the finely broken salt is, unlike the coal, merchantable, the loss in mining solid undisturbed ground at Goderich, should not exceed this. If then, we suppose eighty per cent. of the salt from the white layer of 10¾ feet, to be got in a merchantable shape, it will be equal, for each acre, to a little over 22,200 tons, or 880,000 bushels, so that the product from mining twenty acres of this layer of rock-salt would be equal to the entire salt-production of the United States in 1870.

It is scarcely necessary to enlarge upon the vast economical importance of such a salt-deposit as this, or upon its value to the industry and commerce of the country. In place of the comparatively laborious and costly process of manufacturing salt from brines, in a region remote from coal, where wood is yearly increasing in price, we have offered to the miner a deposit practically inexhaustible in extent and, in large part, of exceptional purity. While the finer qualities of salt may here be cheaply obtained for the supply of the vast and populous regions which are readily accessible by the great lakes, the opening of such mines would yield, at lower rates, salt somewhat less pure, which would be well adapted for the wants of the chemical manufacturer and the agriculturist.

In conclusion, it remains to notice some points relating to the geology of this deposit, and to the occurrence of salt in North America. To the east of the Rocky Mountains, previous to its discovery at Goderich in 1866, rock-salt had been found only in two localities; one of these being at Petite Anse Island near New Iberia, upon the Bayou Têche, in Western Louisiana, and the other at Saltville, Washington County, in Southwestern Virginia. This latter deposit, where rock-salt is associated with gypsum and marls, although situated in the midst of paleozoic rocks, is by Prof. Lesley, regarded as probably of tertiary age, and as occupying a very limited basin. The sources of the brines in the salt-wells of the Ohio valley, and of Saginaw, in Michigan, are supposed to be near the base of the carboniferous series; the Michigan salt-group of Winchell being above the Devonian sandstones, but beneath the limestone which there underlies the coal-measures. Rock-salt has never, so far as I am aware, been detected in the borings at this geological horizon.

The saliferous formation of New York was called by Vanuxem the Onondaga salt group, but to prevent confusion with the Onondaga limestone (a sub-division of the overlying Upper Helderberg group), the synonym of the Salina formation, from the town of Salina (named for its salt-works), near Lake Onondaga, is to be preferred. The Salina formation has a position in the geological column in the upper part of the Silurian series. It rests conformably upon the magnesian limestone of the Niagara formation, and, in Western Ontario, upon a similar rock, which, although apparently an upward continuation of the Niagara, has, for paleontological reasons, been separated from it, and designated the Guelph formation. At its northeastern outcrop, in Montgomery County, New York, the Salina is only a few feet in thickness, but westward, along its northern outcrop, it rapidly augments in volume, and attains in Wayne County a volume of 700, and even in parts, it is said, of 1000 feet. Where it crosses the Niagara River this thickness is reduced to less than 300, and in Ohio, according to Newberry, to less than twenty feet, while Winchell found in Northern Michigan only thirty-seven feet of strata representing the Salina formation. Here, however, the formation is characterized, as in New York and in Ontario, by the presence of gypsum. In its greater development, in New York, it consists, in the lower portion, of variegated red and green marls, overlaid by gray or drab dolomites, and shales containing beds of gypsum, sometimes accompanied by native sulphur in small quantities. Crystalline plates of specular iron ore, as pointed out to me

by Dr. Goessmann, are also sometimes found in druses in the dolomites of this formation.

Overlying the Salina formation are found the Water-lime beds, which are dolomites, like the underlying strata, and contain the remains of *Eurypterus* and some other crustaceans. This division, united with the Lower Helderberg by Vanuxem, is separated alike from it and from the Salina by Professor James Hall, who, however, shows that the Water-lime is more closely related to the Salina, from which it is not always easy to distinguish it. The Lower Helderberg, consisting, at its base, of dark-blue non-magnesian limestone, with tentaculites, succeeded by divisions characterized by pentameri, spirifers, and crinoids, indicates conditions of deposition which were very different from those of the two preceding periods, and did not extend further westward than the centre of the State of New York; beyond which the Lower Helderberg limestones are absent, and those of the Upper Helderberg rest directly on the Water-lime beds, sometimes with and sometimes without the interposition of a thin stratum of silicious rock, representing the Oriskany sandstone. This appears to have been spread over portions of Ontario, but to have been partially removed by erosion before the deposition of the succeeding limestones.

Of the extension of the Salina formation southward beneath the overlying strata, nothing is known until we reach Central Pennsylvania, where, immediately beneath the well-characterized Lower Helderberg (Lewiston) limestone, appears a series of thin-bedded, more or less argillaceous limestones, 580 feet thick, which have been referred to the Water-lime formation. These rest upon 375 feet of fossiliferous limestone and shales, which, in their turn, repose upon the strata of the Clinton formation. Mr. Ashburner, of the Second Geological Survey of Pennsylvania, to whose recently published valuable section we are indebted for these details, suggests that these 375 feet may "represent equally or conjointly" the Niagara and Salina formations of New York, (*Trans. American Philosophical Society*, February 16th, 1877.) It is clear that the conditions which gave rise to the gypsiferous, saliferous, and non-fossiliferous beds of the Salina, did not extend to this region.

No rock-salt has as yet been discovered in the Salina formation in New York, which is nevertheless regarded as the source of the brines of Syracuse and its vicinity. Hopper-shaped cavities, supposed to be due to the removal, by solution, of crystals of salt, are however found in marls at the outcrop of this formation, both in

New York and, farther westward, in Ontario. It is not perhaps generally known that the numerous salt-wells of the Syracuse region, though occurring along the outcrop of the Salina formation, do not penetrate into it, but are sunk in a deposit of stratified sand and gravel, which fills up a valley of erosion, measuring nearly four miles from north to south by two miles from east to west. The marls belonging to the base of the formation crop out to the northward, and are found in the various borings beneath the ancient gravel deposit, which is itself covered by thirty or forty feet of more recent loam or sand. The bottom of the basin is very irregular, the marls being met with at depths of from 90 to 180 feet in some parts, and at a depth of 382 feet in the middle of the basin, the greatest depth of which, according to Mr. Geddes, is not less than 414 feet below the surface-level of Onondaga Lake, and 50 feet below the level of the sea (*Trans. New York State Agricultural Society*, 1859).

We have seen that the outcrop of the Salina formation, passing from New York, with a thickness estimated at less than 300 feet, crosses the Niagara River above the cataract, and enters the province of Ontario, where its distribution has been carefully studied by Mr. Alexander Murray, of the Geological Survey of Canada. By reference to the geological map of Canada, on which the Water-lime beds are included with the Salina formation, and represented by the same color, the series may be traced between the underlying Guelph and the overlying Upper Helderberg (Corniferous) formation, nearly westward from the Niagara River to Brantford, and thence north-northwest to Southampton, at the mouth of the Saugeen River on Lake Huron, a distance of about 180 miles. From this point, its upper limit stretches southward along the lake for fifty miles, to Goderich, where the higher beds of the series disappear, being overlaid to the eastward by the limestone of the Upper Helderberg. Beneath the waters of the lake the outcrop of the Salina turns again to the northward, and reappears in the Duck Islands, south of the Grand Manitoulin, and at the Straits of Mackinac. The arrangement of the strata north and east of Goderich shows the existence of a shallow synclinal dying out to the southward, and inclosing a tongue of the overlying limestones. These, from Goderich, extend for a distance of about forty miles to the eastward, and about the same distance to the northward; Ainsleyville and Teeswater lying nearly in the centre of the synclinal, which is surrounded east, north, and west, by the Salina series.

The belt of this series, of which we have thus traced the distribu-

tion, has a breadth, throughout the whole distance, varying from eight to sixteen miles, and includes, in its upper part, beds having the character of the Water-lime, (affording in some places, near Lake Erie, the characteristic *Eurypterus*) underlaid by dolomitic strata, with gypsum, which is mined in several localities. Some greenish marly beds are found, but nothing is seen corresponding to the great mass of variegated marls which appears at the base of this formation in Central New York, and in the Goderich borings; neither are there any brine-springs known along its outcrop. The whole thickness of these nearly horizontal strata, along the northeast border of the Upper Helderberg limestone, is probably not great, but northwestward, towards Lake Huron, there is evidently a rapid thickening, and a development of saliferous strata in the formation, as is shown in the vicinity of Goderich. The results of the borings at Teeswater, Ainsleyville, Carronbrook, and Mitchell (already mentioned) prove, however, that the eastern limit of this development lies between these places and the lake-shore. Much farther exploration by borings would be necessary before it would be possible to determine whether the salt found farther south, in Bosanquet, Warwick, and Dawn, belongs to the same area as that of Goderich and its vicinity, or whether, like the salt of Syracuse, it occupies a separate saliferous basin at the same geological horizon as these.

In strata underlying the saliferous rocks already noticed as occurring at the base of the coal measures, there exists, in Michigan, another salt-bearing horizon which, it may be conjectured, belongs to the Salina formation. A well bored to a depth of 1198 feet in Port Austin, Huron County, Michigan, on the western shore of Lake Huron, nearly opposite to Goderich, has yielded a strong, though somewhat impure brine, marking 88° of the salometer, which has been analyzed by Dr. Goessmann. This boring is sunk in the Devonian (Portage and Chemung) sandstones of the region, between which and the Salina formation there intervene, on the Canadian shore of Lake Huron, about 400 feet of strata belonging to the Hamilton shales, and 200 feet of the Upper Helderberg limestones. It would appear that we have at Port Austin a considerable diminution in thickness either of the overlying formations or of the Salina formation itself. This latter supposition would agree with the greatly diminished thickness found by Professor Winchell for this formation at its outcrop near Mackinac, where it is reduced to less than 40 feet. A farther discussion of this subject will be found in my report already referred to (*Geological Survey of Canada* for 1869).

Since that time rock-salt has been detected in Huron County, in a boring at Caseville, and farther northward, in 1872, at a depth of 1164 feet, in a boring begun in the same strata at Alpena on Thunder Bay, sixty miles or more west of north from Huron County. These occurrences of rock-salt were made known by Professor Winchell in 1874, but details with regard to them are still wanting. The existence of brines in the counties of Macomb and Iosco, which have a geological position similar to those of Huron and Alpena, has also been announced.

[Since these pages were in print, a paragraph (in April, 1877) in the *Inter-Ocean* journal, of Chicago, states that a well has lately been sunk at Bay City, on Saginaw Bay, in Michigan, with a view of ascertaining whether salt exists below the present brine-producing horizon of that region (which is that at the base of the coal measures, and that a lower stratum of "salt rock," 115 feet in thickness, has been reached at the great depth of 2085 feet from the surface. This, it may be conjectured, belongs to the Salina formation.]

The Lower Helderberg rocks, seen overlying the Salina in Eastern New York, disappear entirely to the west of Onondaga County, and the Oriskany sandstone, regarded as constituting a division between these and the Upper Helderberg, is not found continuously to the west of Cayuga Lake; beyond which, except where isolated patches of the Oriskany intervene, the Water-lime beds are directly overlaid, throughout New York and Ontario, by the Upper Helderberg limestones. These, in New York, are divided by Professor James Hall into a lower member, the Onondaga, described as a gray sub-crystalline coralline limestone, and an upper member, the Seneca or Corniferous, consisting of compact limestones, dark in color, often bluish or blackish, containing few corals, and generally less fossiliferous than the lower, but abounding in chert or hornstone, which sometimes exceeds the limestone in amount.

In Ontario, these divisions of the Upper Helderberg have not been clearly made out, partly for the reason that the strata are much concealed by clays, but the whole mass of limestone, from the Water-lime below to the overlying Hamilton shales, has been included, on the geological map of Canada, under the name of Corniferous, and has a thickness estimated at about 200 feet. On the Maitland River, near the town of Goderich, is a section in which gray coralline limestones, supposed to represent the base of the

Upper Helderberg, repose, with the intervention of a few feet of yellowish sandstone, upon gray bituminous dolomites, which have been regarded as the summit of the Water-lime formation. (*Geology of Canada*, 1863, page 377.) The distribution of the Upper Helderberg limestones to the north and east of this has already been described. It will be remembered that at Clinton, thirteen miles southeast from Goderich, it was necessary to sink to 1180 feet, or 216 feet deeper than at Goderich, before reaching the rock-salt. This may probably be taken as representing approximately the thickness of the overlying Corniferous limestone.

We now come to the consideration of an unexpected result of the examination of the cores from the Goderich boring; namely, the occurrence beneath 278 feet of beds, chiefly dolomite, which, according to the Geological Survey, underlie the Corniferous limestone of the region, of not less than 276 feet, chiefly of gray non-magnesian coralline limestone, abounding in chert, and seeming like a repetition of the Corniferous. Beneath this lower fossiliferous limestone, it will be noted, are dolomites with gypsum, succeeded by variegated marls, with an aggregate thickness of not less than 364 feet, before reaching the saliferous strata, which latter have been penetrated 520 feet without reaching the underlying Guelph formation. Professor James Hall, who has kindly examined such specimens of the corals as I have obtained from this limestone (Division III of the section) recognizes in them two species of *Favosites*, *F. Winchelli* and *F. Emmonsii*, together with a section of *Acervularia* or *Diphyphyllum*.

It might be supposed that these coralline limestones of Division III correspond to the Onondaga (the lower member of the Upper Helderberg), and that the dolomites of II are but a locally intercalated mass, separating this from the proper Corniferous—the superior member. These dolomites have, however, been supposed to be continuous with those which, near the shore of Lake Erie, hold the fossils of the Water-lime formation, and are there overlaid, in part, by the Oriskany sandstone, thus occupying a position inferior to the whole of the Upper Helderberg series. Moreover, there is not, so far as known, any interposed mass of coralline limestone along the belt of magnesian strata, believed to represent the Salina and Water-lime formations, which has been traced from Lake Erie to Lake Huron.

A second hypothesis may be suggested to explain this seeming anomaly. If we suppose that at the time when the saliferous and

magnesian strata of the Salina and Water-lime formations were in course of deposition in cut-off basins, the outer ocean already contained the fauna of the Upper Helderberg time, we may admit that the intercalated mass of coralline limestone, of Division III, was deposited by a temporary influx of the waters of the open sea into a part of the evaporating basin.

The existence of such a saliferous deposit as the Salina, and the great variations in its thickness over adjacent areas, point to local irregularities of surface, which render either one of the above hypotheses not antecedently improbable. In the first, we suppose an intercalation of magnesian deposits in the midst of the non-magnesian coralline limestones of the Upper Helderberg series; and in the second, the interposition of a non-magnesian coralline limestone among the dolomites of the Salina and Water-lime series. Further observations will be required before it is possible to determine which one, if either, of these hypotheses is admissible. It is to be hoped that the mining operations projected for the working of the rock-salt at Goderich, may furnish more extended palæontological evidence, which will be eagerly sought for by geologists.

NOTES ON A METALLURGICAL CAMPAIGN AT HALL VALLEY, COLORADO.

BY J. L. JERNEGAN, JR., M.E., LA GRANGE, CALIFORNIA.

IN the summer and fall of 1875, the author was present during a short smelting campaign at the Hall Valley works, and having had occasion to make a number of chemical analyses of the ores, fuel, and fluxes, deems that the results of the same, and also an account of the smelting operations, may be found of interest to members of the Institute.

The mines and reduction works of the Hall Valley Silver—Lead Mining and Smelting Company (limited) are situated at Hall Valley, Park County, Colorado. The smelting works are located about half way from the mouth to the head of the above-named valley, and the mines high up on the mountains, near its head. The three principal mines of the company are the Whale, Leftwick, and Coldspring. They are all on different veins, running parallel to one another, with a general trend from southwest and northeast. The

country rock is gneiss, in places granitoidal. The general features of these lodes are quite similar to each other, all of them carrying a gangue chiefly composed of heavy spar, the principal metalliferous minerals being argentiferous galena and gray copper. Besides the minerals already mentioned, there occur, more or less frequently, native silver, copper pyrites, iron pyrites, malachite, azurite, copper vitriol, cerusite, anglesite, quartz, chalcedony, and siderite. In general terms, the ore may be said to be composed of a large percentage of heavy spar, quartz, and argentiferous galena, with small amounts of silver-bearing gray copper, the other minerals occurring only in very small quantities. The average assay of the pure galena in silver is about 30 ounces per ton, and that of the gray copper about 300 ounces. Besides the ores of Hall Valley, ores from the adjoining mining districts of Geneva and Montezuma also sometimes find their way to the Hall Valley works for reduction. The ores of these outside districts are all very similar to the Hall Valley ores, their predominating gangue being heavy spar, and thus offer no advantage as mixtures with the latter. The ores from the Geneva District coming to the works are mostly from the Revenue Mine. They carry a great deal of heavy spar and quartz, but are often much richer in silver than the Hall Valley ores, owing to a larger percentage of gray copper, and oftentimes the presence of a rich silver mineral, called bismuth silver.

The ore, on coming from the mines, which are connected with the reduction works by a tramway four and one-half miles in length, is delivered to the dressing works for the purpose of concentration. It is first broken into pieces by passing it through a Blake's crusher, then crushed fine by a pair of Cornish rollers, after which it is classified according to size on a system of shaking sieves. The classified ore is then subjected to concentration, according to specific gravity on double plunger jigs. This system of wet concentration is very imperfect, and gives very unsatisfactory results with the Hall Valley ores, causing as it does a heavy loss in the silver contents of the ore, owing to the impossibility of separating the rich argentiferous gray copper from the heavy spar by means of the difference between their specific gravities, the same being too slight; and yet it is of the utmost importance that the ore should undergo thorough concentration previous to its treatment in the blast furnace, otherwise a large percentage of the very intractable heavy spar would have to be smelted. A large percentage of heavy spar in the ore not only causes in smelting the formation of a slag which is stiff, pasty, and at the same time

difficult of fusion, but also imparts to it such a high specific gravity that it prevents a good separation of matte from slag.

It is a fact well known to metallurgists that sulphate of baryta is only partially decomposed in the blast-furnace, only a portion being slagged off in the form of silicate of baryta, while another portion is reduced to sulphide of barium, and enters the matte, and which, if present in that product in large quantities, causes it to crumble on exposure to the atmosphere; while yet another portion remains entirely undecomposed, and enters the slag and matte as a sulphate. Heavy spar, when fluxed with fluor spar, is melted very easily.

A more thorough system of concentration, *i. e.*, better classification, and the employment of Rittinger's continuously working percussion-table for the working over of the slimes and tailings from the jigs, in conjunction with a system of pointed boxes (*Spitzkasten*) for their classification, would undoubtedly effect a larger saving of the precious metals, and at the same time rid the valuable minerals, to a certain extent, of their accompanying and worthless gangue.

There appeared some time since, in several of the technical papers both of Europe and this country, a description of a process by Mr. Frederick Sturm, an Austrian engineer, for the separation of gray copper from heavy spar, which, should it prove by continued experiment on a large scale to be both practical and economical, would be of the greatest benefit in the treatment not only of the Hall Valley ores, but also of those of several other mining districts of Colorado, where there are ores carrying these two minerals together. The process is founded on the behavior of heavy spar and gray copper when subjected to the action of heat, under the effects of which, when sufficiently high, heavy spar decrepitates into minute rhombohedrons, the gray copper remaining unchanged. This operation having been accomplished, the two minerals are then separated from one another by means of screening. The separation, of course, is not perfect, but, judging from the experiments carried out in Europe, it appears far more complete than that which can be effected by wet concentration.

The two following analyses are of the dressed ore. I is the first-class product from the jigs, and is a mixture of ores from the Whale and Leftwick mines; II is also concentrated ore from the same mines, but with more gangue material than the first, which is explained by the concentration not having been carried as far.

DRESSED ORES.

	I.	II.
Galena,	80.78	68 02
Heavy spar,	11.22	19 38
Iron sesquioxide,	trace	0.08
Alumina,	"	trace
Quartz,	8 00	10 62
	100.00	98.10

The following are some twenty-six determinations of the amount of silica and sulphate of baryta contained in various lots of ore from Whale, Leftwick, and Coldspring mines, and also from mines of the Geneva District. Those containing the very highest percentages of silica were from Geneva, and were of such a character as not to allow of wet concentration. With a few exceptions, all of these lots of ore had been concentrated on the double plunger jigs, before the samples for analysis were taken.

No.	SiO_2, per cent.	BaO,SO_3, per cent.	No.	SiO_2, per cent.	BaO,SO_3, per cent.
1.	1 00	7.00	14.	14.00	12.00
2.	1.00	7.00	15.	14 80	9 00
3.	1.00	7.30	16.	15.00	16.00
4.	1.40	21.00	17.	15 20	13 00
5.	1 50	2.50	18.	15 50	6 50
6.	1.80	5.20	19.	15.80	27 00
7.	3.00	25 00	20.	16 00	17 50
8.	3.50	2.00	21.	16.50	14.00
9.	4 00	8.00	22.	21.00	29.50
10.	5.50	12 30	23.	21.50	27.00
11.	5.80	7.70	24.	21.80	8 20
12.	6.30	12.20	25.	27.50	32.50
13.	9.30	10.20	26.	55.50	14.30

In the fall of the year 1874, Mr. Howard Painter, M.E.,* was offered the position of engineer in charge of the mines and smelting works of the Hall Valley Silver-Lead Mining and Smelting Company. Shortly after taking charge Mr. Painter blew in one of the three large blast-furnaces—known as Kast's modification of the Piltz furnace—and commenced smelting the raw ore in accordance with the well-known method of iron precipitation. A very

* Died in San Francisco, May 15th, 1876.

porous and friable bog iron ore, found on the company's property, was used as the precipitating medium for the sulphide of lead in the ore. In the very high furnaces of the Hall Valley Works, which are 23 feet in height from the centre of tuyeres to top of shaft, this iron ore, by reason of its porosity and very friable nature, proved to be readily reducible to the metallic state long before reaching the zone of fusion. This circumstance very naturally caused the formation of large accretions on the sides of the shaft, which commenced to form eight to ten feet above the tuyeres, and extended nearly down to them. For this reason, it was not many days after the furnace had been started, that it became necessary to blow out. Though this short campaign was not productive of any very good results, it at least led to the conclusion that if the Hall Valley ores were to be successfully treated in these high furnaces, much less of this poor quality of iron ore would have to be used in the future in smelting, otherwise the same difficulty as heretofore would invariably occur.

In order to overcome the necessity of using such large quantities of this iron ore, an entire change in the method of reduction was determined upon by substituting the combined method of roasting and reduction for the iron precipitation process. The adoption of this method would effect a great saving in the use of iron ore, and it was deemed probable that, by subjecting the ore to an oxidizing and slagging roasting previous to its treatment in the blast-furnace, not only the sulphur of the galena, etc., would be expelled, but also that at least a portion of the sulphuric acid of the heavy spar would be driven off by the formation of silicate of baryta during the slagging period. An analysis of the roasted ore, which will be given later, shows, however, that only a very small percentage of the sulphate of baryta is decomposed. Both Plattner and Kerl give two analyses of a roasted ore from Pontgibaud, wherein it appears that a small portion of the sulphate of baryta contained in the ores of that locality is decomposed in the roasting-furnace, the baryta combining with silica to form a silicate (Plattner's *Vorlesungen ueber Allgemeine Huettenkunde*, vol. ii, p. 89, Kerl's *Handbuch der Allgemeinen Huettenkunde*, vol. ii, p. 217). The two analyses cited are given for sake of comparison with the analyses of the Hall Valley roasted ore. The comparison will be found of interrest, for reason of the apparent similarity of the two ores.

ROASTED ORE FROM PONTGIBAUD.

		I.	II.
	Zinc oxide,	0.6	0.7
	Lead oxide,	1 5	3.4
	Iron sesquioxide,	0 7	3 1
	Baryta sulphate,	7.4	7 2
	Lead sulphate,	6 7	7.1
	Lead sulphide,	1.4	5.7
	Silica, quartz, and feldspar,	24 1	16.5
Combined with Silica	Lead oxide,	34.1	37.2
Combined with Silica	Zinc oxide,	3.3	3.4
Combined with Silica	Iron protoxide,	16.3	11.0
Combined with Silica	Magnesia and alkalies,	1.3	1.5
Combined with Silica	Lime and baryta,	1.0	1.1
	Arsenic and antimony,	trace.	trace.
		98.4	97.9
	Total metallic lead,	17 0	39.0

In the summer of 1875 a roasting furnace was erected. This furnace is a long, single-hearth reverberatory, measuring 64 feet in length over all, and 9 feet wide. Roasting was begun as soon as the furnace was finished, and continued until all ore on hand at the works was roasted.

A roasting charge consisted of about 1800 lbs. of finely crushed ore. The furnace held five charges at a time, or 4½ tons. Charges were drawn about every three hours, consequently each charge remained in the furnace 15 hours, and there would be about 7 tons ore roasted per 24 hours, with a consumption of about 2½ cords of wood.

The well-roasted and thoroughly slagged ore was black in appearance, with a slight vitreous lustre, and porphyritic in texture, in consequence of numerous unchanged particles of heavy spar scattered irregularly throughout the fused mass. When not well roasted, bright metallic-looking particles of lead sulphide were visible. The following are analyses of the roasted ore: I is probably a better average of the roasted product than II or III, and also carried out with greater facilities and more care. I will state here that the silica and sulphate of baryta were determined and weighed as one substance and then separated by means of hydrofluoric acid, so there can be no doubt as to the presence of the baryta in form of the sulphate. II is of ore known to carry a higher percentage of lead than the average of the ore roasted. The lead and silver were determined by assay, 5 per cent. having been added to the lead for loss by vola-

tilization. The iron and alumina are merely estimates. The percentage of sulphur given is probably much too high, as it was determined by fusing the ore with bicarbonate of soda and nitrate of potassa, dissolving in water, and titrating with a standard solution of barium chloride. The sulphuric acid of the sulphate of baryta would naturally combine with the soda to form sulphate of soda, which would be dissolved in water and precipitated by means of the barium chloride, and thus give too high a result. In III only the silica and sulphate of baryta were determined.

HALL VALLEY ROASTED ORE.

		I	II.	III.
	Silica,	22.71	15.00	16.00
	Baryta sulphate,	18.36	11.50	16 50
	Lead sulphide,	3.14		
Combined with Silica.	Lead oxide,	39 10	58.94	
	Copper oxide,	1 71	not determined.	
	Silver oxide,	0.21	0.21	
	Alumina,	3.11	0 38	
	Iron protoxide,	3.59	7.00	
	Manganese protoxide,	trace.	trace.	
	Lime,	0.42		
	Baryta,		trace.	
	Magnesia,	trace.		
	Sulphur,		6.97	
		97.35	100.00	
	Total lead,	39.02	55 00	
	" silver,	38 oz.	58 oz. per ton.	

The first mixture of ores roasted amounted to 43,895 pounds, which after roasting weighed 36,000 pounds, assaying 71 oz. silver per ton, and 41 per cent. lead. The loss in weight by roasting was 7895 pounds, or about 17 per cent. The second mixture amounted to 28,983 pounds, and weighed after roasting 24,000 pounds, showing a loss in weight by roasting of 4983 pounds, or about 17 per cent. The average assay in silver was 60 oz. per ton, and 48 per cent. in lead.

As soon as a sufficient amount of roasted ore had accumulated operations were commenced for its reduction in the blast-furnace.

Analysis II of the roasted ore was taken as the basis upon which to calculate the charge. It was determined to so flux the roasted ore with iron ore and limestone that the slag formed should approach a singulo-silicate in its chemical composition. Complete analyses

were, therefore, made of the roasted ore, limestone, iron ore, and ash of the coke, in order to acquire a thorough knowledge of everything going into the furnace. The limestone came from South Park, near the town of Fairplay. The iron ore was burnt in free heaps before use, in order to free it from its water of hydration. The following make-up of the charge was decided upon, to be changed at any time, of course, should circumstances require it. At first, a small quantity of metallic iron was used in place of iron ore, as long as the limited supply on hand lasted, after which iron ore was substituted in its place.

BLAST FURNACE CHARGE, FIRST RUN.

	Per ton ore. Pounds.	Per cent.
Roasted ore,	2000	58.71
Limestone,	380	11.15
Burnt iron ore,	360	10.56
Scrap iron,	166	4.90
Old slag,	500	14.68
	3406	100.00
Coke,	500	
	3906	

The proportion of coke to charge is about as 1 to 7. The slag added to the charge was of three separate lots brought from the smelting works at Alma. They contained respectively 52, 46.8 and 45 per cent. silica. The slag actually produced in practice from the smelting of this charge was sampled, and the silica determined and found to amount to 32.70 per cent., therefore very close to what was desired.

One of the blast furnaces was blown in, and ran for several days on the above charge, producing a thin fluid slag containing 32.70 per cent. silica, assaying only 1 per cent. in lead, and $\frac{5}{7}$th oz. in silver per ton. The matte separated well from the slag, was of a bronze-like color, and appeared to be principally composed of protosulphide of iron. It assayed about 7 oz. silver per ton. The bullion carried about 150 oz. per ton.

In spite of the good quality of the slag, on the third or fourth dry after blowing in, the furnace commenced to work very poorly. Very little lead was being reduced, and the charges commenced sinking irregularly, seeming to hang somewhere high above the tuyeres, since the crucible was perfectly clear and all the tuyeres bright.

The furnace was therefore blown out after having run about 96 hours. Upon examination after blowing out, the furnace was found to have a large accretion extending all around the shaft, about 8 feet above the tuyeres, leaving only a small annular space, measuring some two or three feet in diameter, for the charges to pass through. The cause of its formation was attributed to the reduction of the iron ore in the charge to the metallic state before reaching the zone of fusion, which prevented it entering the slag as a silicate of the protoxide, the soft spongy iron thus formed adhering to the walls and thereby forming a nucleus for the growth of a large mass.

It was therefore determined at the second trial to use much less iron ore, and produce a slag containing 40 per cent. silica, so as to give the iron every possible opportunity of forming a silicate, and thus prevent its reduction, as far as possible, to the metallic state.

In order to see how the blast-furnace charge used in the first trial smelting would compare with a charge accurately calculated in accordance with stochiometrical principles from analysis I of the roasted ore (which in all probability is a better average than II) we will proceed to make the calculation. This calculation will also prove of interest by enabling us to judge whether there was more iron ore used than was actually necessary, and whether or not it was owing to an excess of basic fluxes that the poor working of the furnace could be attributed.

For sake of convenience in the calculation we will again give analysis I of the roasted ore, not in the form of rational results, but empirical, since the latter are those which will be necessary in carrying out the calculation.

ROASTED ORE.

Silica,	22.71	Alumina,	8.11
Lead oxide,	42.04	Lime,	0 42
Copper oxide,	1.71	Baryta,	12.05
Silver oxide,	0.21	Sulphuric acid,	6.31
Iron protoxide,	3.59	Sulphur,	2.94
			100.09
Total metallic lead,			39.02

The following formula will represent approximately the chemical composition of the slag desired, viz. A singulo-silicate.

$$2Al_2O_3,3SiO_2 + 2(BaO,MgO,CaO,FeO,MnO)SiO_2.$$

We will first proceed to calculate the necessary amount of silica to form such a slag with the different bases given in the analysis of the roasted ore.

Assuming that the sulphate of baryta is completely decomposed, and the baryta enters into chemical combination with the silica; then to determine how much silica the baryta requires, we have the proportion:

$$2 \text{ eq. } BaO : 1 \text{ eq } SiO_2 :: \text{per cent. } BaO : x.$$
$$153 : 30 :: 12\ 05 : x.$$

x equals 2 36, therefore 12 05 p. c. BaO requires 2.36 p. c. SiO_2.

For the protoxide of iron we have:

$72 : 30 :: 3\ 59 : x$, $x = 1.49$; hence 3.59 p. c. FeO takes up 1.49 SiO_2.

For the alumina we must take 2 eq. Al_2O_3 to 3 eq. SiO_2; we then have:

$102.4 : 90 :: 8\ 11 : x$, $x = 7.12$; so 8.11 p. c. Al_2O_3 takes 7.12 p. c. SiO_2.

For lime we have:

$56 : 30 :: 0.42 : x$, $x = 0.22$; therefore 0.42 p. c. CaO saturates 0 22 p. c. SiO_2.

Hence we find that:

12.05 p. c. BaO	saturates	2 36 p. c. SiO_2.	8.11 p. c. Al_2O_3	saturates	7.12 p. c. SiO_2.
3 59 " FeO	"	1.49 " "	0 42 " CaO	"	0.22 " "
					11.19 p. c. silica.

The silica in the roasted ore saturated by bases in same amounts to 11.19 per cent. of the total quantity, which still leaves 11.52 per cent. to be fluxed by the addition of limestone and iron ore; this is equivalent to 2304 lbs. per ton of roasted product.

The ash of the coke must also be taken into consideration. We will allow of a consumption of ¼ ton coke per ton of roasted ore smelted. The coke on analysis was found to contain 10.72 per cent. ash, of the following composition:

COKE ASH.

Silica, . .	46.64	Lime, ...	6.00
Iron sesquioxide,	22 00 = 19.80 FeO	Magnesia, ...	1.00
Alumina, . .	25.00		100.64

Following the same method as before, we find:

19 80 p. c. FeO	saturates	8 25 p. c. SiO_2	6.00 p. c. CaO	saturates	3.21 p. c. SiO_2
25.00 " Al_2O_3	"	21.97 " "	1.00 " MgO	"	0.75 " "
					34.18 p.c. silica.

Therefore the silica in the ash of the coke saturated by bases in same amounts to 34.18 per cent., which consequently leaves 12.46 per cent. SiO_2 unsaturated, or 26.71 lbs. SiO_2 per ton of coke, but since it is assumed that only $\frac{1}{4}$ ton of coke is consumed per ton of ore smelted, there can only be 6.67 lbs. SiO_2.

Hence we have for one ton roasted ore:

Free SiO_2 in 1 ton of ore, ...	230 40 lbs.
Free SiO_2 in $\frac{1}{4}$ ton of coke, ...	6 67 lbs.
Free SiO_2 with 1 ton of ore, ...	237.07 lbs,

to be saturated by bases in limestone and iron ore.

An analysis of the limestone which came from South Park, near the town of Fairplay, afforded:

LIMESTONE.

Silica, . . .	2.50	Clay and sand, . . .	2.00
Iron sesquioxide, .	1.00 = 0.90 FeO.	Organic matter, . .	0 35
Alumina, . .	1.00	Carbonic acid, . . .	41.14
Magnesia, . .	6.50	Water, ...	2.61
Lime, . . .	43.26		100 36

By the same method of calculation we find:

1.00 p. c. Al_2O_3 requires 0 87 p. c. SiO_2.
0.90 p. c. FeO " 0.37 p. c. SiO_2.

1.24 p. c. silica.

There are 1.24 per cent. SiO_2 saturated by the iron protoxide and the alumina, leaving 1.26 per cent. SiO_2 yet to be saturated. This will require exactly 1.68 per cent. MgO, so that the limestone after all silica is saturated (not taking into consideration the small amount of clay and sand) is represented by:

CaO = 43.26 p. c.
MgO = 4.82 p. c.

48 08

Now one of lime in forming a singulo-silicate takes up 0.53 per cent. SiO_2, and one of magnesia combines with 0.75 per cent. SiO_2; consequently 1.43 lime is equal to 1 magnesia, but there are 4.82

per cent. MgO, which are equal to 6.89 per cent. CaO. The entire limestone is then equivalent to:

$$
\begin{array}{rl}
4.82 \text{ p. c. MgO} = & 6\ 89 \text{ p. c. CaO.} \\
& 43\ 26 \text{ p. c. CaO.} \\
\hline
& 50.15 \text{ p. c. lime.}
\end{array}
$$

Which is equivalent to 1003 lbs. free CaO in a ton of limestone. An analysis of the burnt ore afforded:

BURNT IRON ORE.

Iron sesquioxide,	93 00 p. c.	$= 83.80$ FeO $= 65.10$ Fe.
Alumina,	0.50 p. c.	
Silica,	7 00 p. c.	
	100.50	

The 0.50 per cent. Al_2O_3 requires 0.44 SiO_2, leaving 6.56 per cent. SiO_2 unsaturated; this will require exactly 7.87 per cent. FeO, so that the burnt iron ore, after all silica is saturated, is represented by

$$FeO = 75.83 \text{ p. c.} = 65\ 10 \text{ p. c. Fe.}$$

This is equivalent to 1516.6 lbs. free protoxide of iron, or 1302 lbs. of free metallic iron per ton of burnt iron ore.

There are 237.07 lbs. free silica per ton of roasted ore and ½ ton coke to be neutralized by the addition of limestone and iron ore; then saturating with lime to iron as 1 to 1:

$$
\begin{array}{l}
1 \text{ eq. } SiO_2 : 2 \text{ eq. } CaO : : 118\ 535 \text{ lbs. } : \text{lbs. CaO.} \\
\quad 30 \quad : \quad 56 \quad : : 118\ 535 : x., x = 221\ 29. \\
1 \text{ eq. } SiO_2 : 2 \text{ eq. } FeO : : 118\ 535 : \text{lbs. FeO.} \\
\quad 30 \quad : \quad 72 \quad : : 118.535 : x., x = 284.45.
\end{array}
$$

It will therefore require 221.29 lbs. lime, and 284.45 lbs. protoxide of iron to saturate the silica in one ton of roasted ore and ½ ton coke. There are 1003 lbs. free lime in one ton of the limestone, and 1516.6 lbs. free protoxide of iron in the burnt ore, consequently it will require 0.22062 ton limestone, and 0.18755 ton iron ore, or 441.24 lbs. limestone, and 375.1 lbs. iron ore; together 816.34 lbs. fluxes per ton roasted ore and ½ ton coke.

This would give a slag of the following composition:

	Lbs. in Ore and Coke		Lbs. in Limestone.		Lbs. in Iron Ore.	Total.	Per cent.
SiO_2 =	479.19	+	11.85	+	35.00 =	526.04 =	30.88
Al_2O_3 =	175 60	+	4.74	+	2.50 =	182.84 =	10.73
BaO =	241 00	+			=	241.00 =	14.15
FeO =	82.42	+	4 26	+	418.50 =	505.18 =	29.60
CaO =	11.61	+	205 05		=	216 66 =	12 72
MgO =	0.53	+	30.81		=	31.34 =	1.92
						1703.06	100.00

Silica, ...	30.88 =				16 46 Oxygen in acid.
Alumina, ...	10.73 =			5 02	= 17.45 Oxygen in bases.
Baryta, ...	14.15 =	1.47	= 12 43		
Iron protoxide, . .	29.60 =	6.57			
Lime, ...	12.72 =	3.63			
Magnesia, . . .	1.92 =	0.76			
	100 00				

The oxygen of the bases of the RO type amounts to 12.43, and that of the R_2O_3 type to 5.02, and that of the silicic acid to 16.46. The sum of the oxygen of both types of bases is 17.45. This gives the ratio of 17.45 : 16.46 = 1.06 : 1, or nearly as 1 : 1. The slag consequently approaches as nearly to a singulo-silicate as it is possible to calculate by using two places of decimals only. Since the oxygen of the bases of the RO type is to that of the R_2O_3 type as 12.43 : 5.02 = 2.47 : 1, or nearly as 2 : 1, the composition of the calculated slag may be approximately represented by the formula:

$$4Al_2O_3,6\,SiO_2 + 2RO,SiO_2.$$

The roasted ore contains 39.02 per cent. metallic lead, so there will then be used 1130.8 limestone, and 961.2 lbs. iron ore, or 2.092 lbs. flux per ton of bullion produced, the more or less unavoidable loss in lead not being taken into consideration. Theoretically, the bullion would contain 148½ ozs. silver per ton. Per ton of roasted ore there would be used 0.22062 ton limestone, and 0.18755 ton iron ore; or together 0.40837 ton = 816.34 lbs. fluxes = 40.83 per cent. of the roasted ore; and there would be produced 1703 lbs. slag per ton ore, or 4338 lbs. = 2.169 tons, per ton bullion produced, plus the amount of old slag added to the charge.

There is 2.94 per cent. sulphur in the roasted ore, which will go to form a matte with the copper; but since there is only 1.36 per cent. of the metallic copper contained in the ore to combine with the sulphur to a matte, expressed by the formula Cu_2S, there remains 2.60 per cent. sulphur uncombined, since 1.36 per cent. copper requires only 0.34 per cent. sulphur to form the salt above mentioned.

This excess of sulphur would combine with lead to form PbS, if not prevented by the addition of iron. The sulphuric acid of the sulphate of baryta would probably be partially reduced to sulphur, but as it would most likely form sulphide of barium, which would be dissolved by the matte and slag, we will not bring it into the calculation. In order to saturate the excess of sulphur, an addition of 4.55 per cent. metallic iron is necessary to form a protosulphide of iron per ton roasted ore. The burnt iron ore contains 65.10 per cent. free metallic iron, consequently there should be added 128.56 lbs. iron ore. We thus form a matte approximating the formula:

$$Cu_2S + FeS.$$

There would be produced per ton of roasted ore smelted, 214.56 lbs. matte, containing:

	Per cent.
Copper,	12 67
Iron,	65.59
Sulphur,	21.74
	100.00

The proportion of matte formed to bullion pródnced would be as 1 : 3.6. There would also be produced a small amount of slag formed from the impurities of the iron ore added to saturate the excess of sulphur.

We now reach the following result as regards the make-up of the blast-furnace charge; a charge that is intended to produce an easily fusible slag that approaches a singulo-silicate in its chemical composition, a matte containing all the copper and no lead, and a bullion carrying all the silver; a result, however, that can be achieved on paper, but not in the blast-furnace.

CALCULATED FURNACE CHARGE.

			Per cent.
Roasted ore,	2000.00 lbs.	=	58 05
Limestone,	441.24 "	=	12.88
Burnt iron ore,	503.66 "	=	14.61
Slag from first run,	500.00 "	=	14 46
	3444.90 "		100.00
Coke,	500.00 "		
	3944.90 "		

Coke to ore as 1 . 4, and coke to charge as 1 : 6.88.

We now have for the calculated charge and the charge used in the first run the following comparison:

	Calculated. Per cent.	First run. Per cent.
Roasted ore, . . .	58.05	56 98
Limestone, . . .	12.88	10 87
Burnt iron ore, . .	14.61	17 57 (metallic iron taken as ore).
Slag from first run, .	14.46	14 58 (from Alma).
	100.00	100 00

It will be perceived that the charge of the first run compares quite closely with the one calculated, with the exception of the amount of iron ore, which is in excess of that required as determined by the calculation by 2.96 per cent.

A few days after the first furnace was blown out, a second was blown in, and smelting was commenced with the following charge:

FURNACE CHARGE, SECOND RUN.

			Per cent.
Roasted ore, ...	2000 lbs.	=	62.89
Limestone, ...	380 "	=	11.94
Burnt iron ore, ...	300 "	=	9 43
Slag from first run, ...	500 "	=	15 74
	3180 "		100.00

This charge varies from that of the first run thereby that the amount of iron ore was reduced by one-half. It produced a slag that ran well, though much richer in lead than that of the first run. Upon analysis it was found to contain 42.20 per cent. silica; it was therefore between a singulo- and a bi-silicate. Slag and matte did not separate as well as in the first run, and the latter also assayed higher in silver and lead. Roasted matte, containing 40 per cent. sesquioxide of iron, was added to the charge for a short time as a substitute for the iron ore, but as it had been roasted in stalls, and had only received one fire, it was soon discontinued on account of containing too much sulphur, and consequently made a large proportion of matte, rich both in lead and silver.

Notwithstanding the large reduction in the amount of iron ore used, and the production of a slag much more highly silicated than that of the first run, the second trial did not turn out much better than the first. The same difficulty was encountered as heretofore, *i. e.*, accretions forming above the tuyeres at about the same height as before, and this time also on the bottom of the crucible, the former

preventing the charges from going down regularly. The furnace ran five days, and was then blown out. During the forepart of this run, in order to overcome, as well as possible, the excessive height of the furnace, the same was only charged to within six feet of the top, but this soon had to be discontinued, as it was found almost impossible to charge the alternating layers of fuel and ore mixture with any degree of regularity.

Thus ended the unsuccessful smelting campaign of the Hall Valley Works in the fall of 1875, affording very unsatisfactory results, similar in many respects to that experienced by almost all new undertakings in the smelting line in this country, which it would almost seem requires the going through with of one or more failures before entire success is reached.

In my opinion, the failure of these attempts at successfully smelting the Hall Valley ores may, without doubt, be attributed to the disadvantageous shape of the shaft-furnaces, and the poor quality of the iron ore used as flux. The furnaces, on account of their great height and small dimensions at level of tuyeres are better suited by far for the reduction of iron ores than for the smelting of those of lead. The iron ore used as a flux would undoubtedly answer its purpose well enough in furnaces of less height.

As far as making a technical success with the smelting of the Hall Valley ores, I can see no difficulty in the future, if the ores are concentrated to such a degree that their percentage of lead is sufficiently increased to insure good smelting, and the latter operation is conducted in properly constructed blast-furnaces, not over ten feet in height from centre of tuyeres to feed-hole, subsequent to a thorough oxidizing and slagging roasting of the ore.

DETERMINATION OF CARBON IN IRON AND STEEL.

BY ANDREW S. M'CREATH, CHEMIST, SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA, HARRISBURG, PA.

THE treatment which a steel receives, and the uses to which it may be applied, are frequently determined by the percentage of carbon which it contains; and especially is this the case in the different steel works in this country. The part which this element plays in the composition of steel is such an important one that a process for its accurate determination becomes an absolute necessity.

At the meeting of the Institute of Mining Engineers, held at Cleveland in October, 1875, Mr. John B. Pearse read an able and exhaustive paper on "Iron and Carbon Mechanically and Chemically Considered," in which he reviewed the history of the chemical work relating to carbon in iron. It will not, therefore, be necessary to go over this ground again and show that the processes hitherto used for the estimation of carbon are often tedious and generally very unreliable.

The Eggertz colorimetric test is now in general use in the different steel works, and, where properly conducted, seems to answer all the requirements for an intelligent treatment of the steel in the forge and rolling mill. As, however, the accuracy of this test is in the first place dependent on a correct estimation of the carbon in the "standard," it becomes an absolute necessity that we should have a thoroughly reliable method for ascertaining this.

It has been proved that in the ordinary process for the estimation of carbon by dissolving the iron or steel in chloride of copper a loss of carbon takes place, owing to the disengagement of certain carburetted hydrogen gases ($C^n H^n$); but according to the investigations of Prof. Richter, this only occurs when the chloride of copper is not perfectly neutral. He therefore suggested the use of a double salt of chloride of copper with chloride of potassium, or chloride of sodium. He found that these salts were easily obtained crystallized and perfectly neutral, and when the decomposition of the iron took place in these solutions under as perfect seclusion of the air as possible, there was not the slightest trace of the carburetted hydrogen gases given off, even though the reaction was hastened by warmth. Another great advantage obtained by the use of these double salts was that it was not necessary to use hydrochloric acid to remove the precipitated copper. In order to effect this it was only necessary to use a considerable excess of the double salt. Indeed, in the first decomposition, if an excess of the double salt had been used under the application of heat, it frequently happened that no separation of copper took place, and that only cuprous chloride was formed, which remained as a soluble double salt in the solution. The action of this double salt, therefore, seemed to suggest a ready and safe method for the separation of iron and carbon. I made several experiments with the use of the double chloride of copper and potassium, and, while the results were thoroughly reliable, the solvent action of the salt seemed rather slow. I was therefore induced to try the double chloride of copper and ammonium, and this I found to work admirably and answer

every purpose. By using a large excess of the salt, the metallic copper, which sometimes separates, is completely dissolved, thereby avoiding acid and consequent liability to a loss of carbon. The solvent action of this salt is such that three to four grams of iron or steel can be completely dissolved in about fifteen minutes. Another advantage is that the iron can be used in coarse drillings, so that the liability to obtain an unfair specimen by rejecting the larger pieces may always be avoided.

The details of the process are as follows:

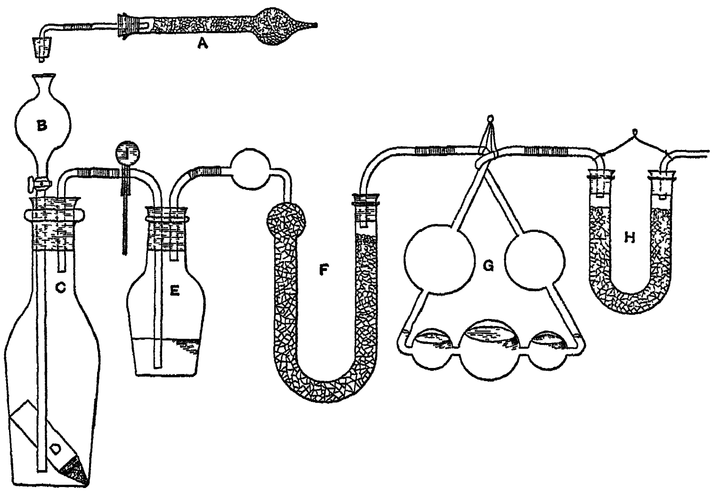
Thirty-six grams of the double chloride of copper and ammonium are dissolved in about 120 cubic centimeters of distilled water; three grams of the iron or steel are then accurately weighed off and added to the solution. Decomposition immediately takes place, iron and copper replacing each other. In order to aid solution the mixture is frequently stirred, and after a few minutes a gentle heat may be applied. In about fifteen minutes the iron will be completely decomposed, and the excess of the double salt will have redissolved any metallic copper which may have separated out. At this stage of the process the solution is so neutral that upon being heated a thin film of iron oxide forms, but this can be easily removed by a few drops of muriatic acid, and the mixture is now ready for filtration. The carbon is collected in a small test-tube about 7.60 centimeters long, and 1.50 centimeters internal diameter, the end of which is drawn out to a point 4 millimeters wide, and stopped first with angular pieces of glass, and then *loosely* with ignited asbestos.

A small quantity of hot water is first run through the filter; the solution is then added, and the residue washed with hot water until free from chlorides. It sometimes happens that a small quantity of basic chloride of copper separates out in the tube, but this is easily dissolved by a little of the double chloride solution, and the washing is continued till the residue is free from chlorides. To see whether any of the carbon passes into the filtrate, mix the fluid with strong hydrochloric acid (to prevent the separation of any basic chloride of copper), and then dilute. By this means it is easy to recognize any particles of carbon. If the filter has been properly made, the solution filters very rapidly, and all the carbon is retained on the asbestos.

The carbon is now to be converted into carbonic acid, and the weight of the latter ascertained. To accomplish this several methods can be used. The transferring of the carbon residue is always attended with trouble, and there is even danger of losing some of it, so that

a method should be used which avoids this objection. A modification of Ullgren's process answers this purpose very nicely. The carbon can be oxidized at once without being dried—an operation which is necessary when it is burned off in oxygen.

The apparatus used for this purpose is shown in the accompanying sketch. A is a tube filled with small pieces of caustic potash, and attachable to funnel-tube, B, by a cork; B is provided with a glass tap, and serves to introduce the acids. The flask, C, has a



capacity of about 300 centimeters, and the wash-bottle, E, about 100 cubic centimeters; the latter is filled about one-third with strong sulphuric acid. The U-tube, F, which has a height of 11 centimeters and an internal diameter of 1.25 centimeter, is filled with angular pieces of chloride of calcium (*free from lime*) to retain the last traces of moisture. The potash-bulbs, G, and the U-tube, H, are for collecting the carbonic acid. The potash solution used in the bulbs should have a density of about 1.27, and the quantity should be sufficient to nearly fill the lower three bulbs. The left arm of the U-tube, H, is filled with angular pieces of caustic potash, and the right arm contains small pieces of chloride of calcium. The bulbs, G, and the tube, H, are carefully weighed before being attached to the apparatus. All being ready, the small test-tube, D, containing the carbon residue, is transferred to the flask, C, as shown in sketch. Three grams of chromic acid are then dissolved in about 10 cubic centimeters of distilled water, and added to the flask, C, by means of the funnel-

tube, B; add to the contents of the flask about 50 cubic centimeters of strong sulphuric acid (through funnel-tube, B), a small quantity at first, then mix the contents of the flask by shaking, and add the rest. Mix the contents thoroughly and heat the flask gently, so that the bubbles of gas do not pass through the wash-bottle, E, faster than three to a second. When the gas has ceased to be evolved, boil the contents of the flask carefully for three or four minutes; then attach the tube, A, remove the lamp, and open the tap of the funnel-tube, B. Having done this, attach an aspirator to the U-tube, H, and draw about four liters of air through the apparatus, not faster than three bubbles to a second. When the heat is withdrawn it frequently happens that the condensation of the vapor is so rapid that the liquor in the wash-bottle, E, rushes back into the flask, C. In order to control this it is advisable to attach a small compression-cock, I, and by this means all trouble is avoided. By this method, as described, an estimation of carbon can be easily made in an hour; and in steels, where the amount of silicium is very small, the carbon may be collected on a counterpoised filter, dried, weighed, and burned off in a platina crucible. This will enable a number of experiments to be carried on at once; but where the chromic acid method is used, a single estimation requires constant attention. The following are some of the results obtained by the use of this process:

Double chloride of copper and potassium, and oxidation with chromic acid, .510, .519, .494, .504, .502.

Double chloride of copper and ammonium, and oxidation with chromic acid, .490, .502, .500, .510.

Double salt, and counterpoise filter, .500 and .510.

The double chloride of copper and ammonium works the quickest and gives equally satisfactory results.

I am indebted to Mr. Joseph Hartshorne for the accompanying sketch of the apparatus used.

THE FRANKLINITE AND ZINC LITIGATION CONCERNING THE DEPOSITS OF MINE HILL, AT FRANKLIN FURNACE, SUSSEX COUNTY, N. J.

BY JOSEPH C. PLATT, JR., WATERFORD, N. Y.

IT is not the object of the present paper to give a description of the minerals found on Mine Hill, in Sussex County, N. J., nor even to touch upon all the forms of the ores named, but to place upon record and call to the attention of the Institute some interesting facts concerning them.

In May, 1875, after the Dover meeting, some of the members visited this locality, and, no doubt, it is fresh in their memories, being one of the best known mineralogical points in our country. It will be only necessary to describe it very briefly.

Mine Hill and Stirling Hill, in Sussex County, N. J.,—the former being at the village of Franklin Furnace, and the latter near Ogdensburg,—are the only localities in the State where zinc ores are found in workable quantities.* Mine Hill is the more northerly, and mineralogically differs from its neighbor, chiefly in having no hydrated ores to speak of, while at Stirling this deposit is considerable. At both points Franklinite, red oxide, and silicate of zinc occur in large quantities.

Mine Hill lies on the east side of the Wallkill River, above which it rises to an extreme elevation of about 150 feet. On the summit the outcrop of the Franklinite vein appears, while the lowest worked points are perhaps 10 or 15 feet above the level of the stream. Commencing at the northern end, where the Hamburg Road crosses it, this outcrop runs along the northwestern brow of the hill a distance of about 2000 feet, in a general southwest direction, to a point where is a large, cavern-like opening, called the "Southwest Opening." "Double Rock," about the highest point on the hill, lies near the middle of this 2000 feet of outcrop, and over or near it passes a property line, to which allusion will hereafter be made. At the Southwest Opening the vein bends abruptly towards the east,—the angle between the two parts being perhaps 45°,—and this easterly branch continues some 700 feet. From the northern part of the Stirling Hill deposit to the southern part of the Mine Hill deposit is about two miles, and in this interval the vein carrying Franklinite

* See New Jersey State Geology, 1868, p. 669.

and zinc is lost, the Southwest Opening on Mine Hill being its first reappearance, and the fork or angle in the vein being one of its most remarkable features. The easterly and short branch has a larger proportion of the red oxide and silicates of zinc than the longer branch, and has been called the Zinc Vein, while the other, having an excess of Franklinite, has been called the Franklinite Vein. These names we retain for present use, although the Franklinite Vein, at its northern extremity, carries a much larger proportion of zinc ores than it does south of Double Rock.

The large openings on these veins are four in number, viz., the Hamburg Road Mine, the Southwest, the Tunnel, and the Buckwheat openings. Small openings, test-pits, etc. (one of which is called the Weights and Measures Opening, because from it, it is said, ore was once taken with a view of making from the metal some standard government weights and measures), are found at various points. The Hamburg Road and Southwest openings have not been worked for some years, nor have the small openings, but the Tunnel and Buckwheat openings have yielded enormous quantities of ore. These are on the so-called Zinc Vein, and have been worked by the New Jersey Zinc Company, and the product, as we understand, mostly used by them at their works in Newark, N. J. Recently a considerable amount was shipped to Bethlehem, Pa. In this mining by the New Jersey Zinc Company a large amount of Franklinite has been removed and shipped with the oxide and silicate of zinc, and this fact has caused years of litigation, which now appears ended by a decision of the United States Circuit Court, at Trenton, in the case of Moses Taylor (of New York) *v.* The New Jersey Zinc Company.

The New Jersey Zinc Company—the defendants in the suit—maintained that the "zinc ores" belonged to them, and that Franklinite, being valuable for its zinc, was included in the zinc ores, and referred to a previous decree of the Court of Appeals of New Jersey in their favor after a trial of the same question. They also claimed that the United States court had no jurisdiction, on account of some question in the passing of real estate papers. The United States court decided that it did have jurisdiction, and the case then hung upon the questions, "*What is Franklinite?*" and "*What was meant by Franklinite by the parties who first sold the minerals in whole or in part?*" To answer these questions, the titles must be referred to.

Prior to 1848 the whole of Mine Hill belonged to Dr. Samuel Fowler, but in March of that year he sold to the Sussex Zinc and

Copper Mining and Manufacturing Company, briefly called the "Sussex Company," "all the zinc, copper, lead, silver, and gold ores, and also all other metals or ores containing metals (*except* the metal or ore called Franklinite, and iron ores where it exists separate from the zinc) existing, found, or to be found" on Mine Hill.

At the same time, with this conveyance of March 10th, 1848, *reserving* certain ores, Dr. Fowler conveyed to the same Sussex Company "all the metal, mineral, or iron ore usually known and designated by the name of Franklinite, found or to be found" on *one* of the tracts of land described in the first deed, this was the tract *north* of Double Rock, previously alluded to; and by these two deeds the Sussex Company became possessed of "all the zinc, copper, lead, silver, and gold ores, and also all other metals or ores containing metals," *and* of the "Franklinite"—in fact, of *all* the ores and metals, *except iron ore*, lying on Mine Hill *north* of Double Rock; and of all ores EXCEPT *Franklinite* AND *iron ores south* of Double Rock.

On December 13th, 1850, Dr. Fowler conveyed to Curtis & Curtis, trustees, "all the reserved ore called Franklinite, and all other reserved ores and metals not granted or conveyed to the Sussex Co." and found on Mine Hill, and February 26th, 1853, Curtis & Curtis conveyed to the New Jersey Franklinite Company "all that portion of the reserved Franklinite and other reserved ores and metals" conveyed to them by Fowler, and to be found on the south side of Mine Hill—*i. e.*, south of Double Rock. This placed the title to the Franklinite south of Double Rock in the New Jersey Franklinite Company, and from them it came, after various sales and foreclosures, to the complainant in the recent case, Mr. Moses Taylor, of New York.

The complainant's bill opening the case was filed in May, 1870, and the claim was that he was entitled to the "mineral known and designated by the name of Franklinite," as it was understood at the time of the conveyances, and as excepted by Dr. Fowler in his conveyances of 1848.

What did Dr. Fowler mean by his "exceptions?" The defendants claimed that, to be covered by them, the Franklinite must be found in crystals (cabinet specimens), or must be *entirely* free from oxide or silicate of zinc. The complainant held that Dr. Fowler intended to reserve the large mass of Franklinite to which he alluded in a letter to a Dr. Phillips, in November, 1827, in which he speaks of "a large black mountain mass at Franklin, considered by Berthier, ... of Paris, as a new metalliferous combination called Franklin-

ite, containing 66 per cent. of iron and 17 of manganese. . . . . Near the Franklinite are . . . veins of iron ore. Accompanying the Franklinite is the red zinc ore, extending the same distance."

It may be remarked here that all throughout this vein the red oxide and silicate of zinc are together and the Franklinite by itself, generally speaking, although at places much mixed. Two veins of iron ore are nearly parallel to the Franklinite vein and within 25 to 200 feet.

A large number of witnesses were examined who testified as to what was called Franklinite in years past, before the use of lime in working the silicate of zinc was discovered, and when the Zinc Company only used the red oxide. Other witnesses for the defence (the Zinc Company) testified that the most valuable ingredient in the Franklinite was zinc, and this being the case they claimed that it was a zinc ore, and therefore belonged to the defendant. But the proof being ample that the black mass occurring in such large deposits was what was, at the time of the conveyances, etc., known and called Franklinite, although it had in it some particles of red oxide and silicate mechanically mixed, and although it was more valuable for its zinc than its iron or manganese, this proof was considered conclusive, and the decision of the court was that an injunction issue against the defendants, and an account be taken of what they had thus far removed.

If this decision stands without appeal, or is, if appealed, sustained by the higher court, it will confirm the view that when any party, A, conveys or leases to another party, B, any mineral or mineral property, the mineral is held to be defined by the understanding A has of it, and not by what future generations may find it to be. If A thinks it is gold ore and sells it as gold ore, and B buys it as gold ore, it *belongs* to B and his successors, whether it is really true gold or turns out to be "fool's gold." If A had at the same time of his sale to B, or prior thereto, sold to C all metals and minerals containing iron and other minerals except "gold ore," then this so-called "gold ore" would belong to B, the fact that it did *not* contain gold and *did* contain iron to the contrary notwithstanding. A's understanding and intention to convey a certain mineral are the governing points, as Dr. Fowler's intention to convey the red zinc ore to one party and the black mass of Franklinite to another governed the recent case.

It was ably contested by eminent counsel on both sides, and the decision has been given within the last few weeks.

NOTE.—Since the meeting of the Institute we are informed that the decree has been issued and a master appointed to take account of Franklinite which the Zinc Company had removed, they being by said decree perpetually enjoined from removing more.

THE ALLOUEZ MINE AND ORE DRESSING, AS PRACTICED IN THE LAKE SUPERIOR COPPER DISTRICT.

BY CHARLES M. ROLKER, E. M., RENO, NEVADA.

THE Allouez Mine is situated in section 31, town 57, north of range 32 west, Michigan. The mine is being worked in a conglomerate bed, which conglomerate is generally conceded to be the continuation of the Albany and Boston conglomerate of Houghton County. Besides the well-known Calumet and Hecla with the adjoining Osceola, both working on the same bed, and the new location, the Seneca, now being tried on the Kearsarge conglomerate, the Allouez Mine is the only one working on a conglomerate bed. The Albany and Boston, in Houghton County, of which, as said before, the Allouez is supposed to be the continuation, shares with all the remaining conglomerate beds, near and around Portage Lake, the property of being non-quartziferous, while the conglomerates of Keweenaw County are all highly quartziferous in character. This change takes place, according to Professor Pumpelly, about six miles northeast of Portage Lake. The Allouez conglomerate, with a dip of 38° 15′ and a general course of about 36° east of north, is overlaid by a trap, and has as its footwall an amygdaloid. The trap is followed by a series of amygdaloidal melaphyres and true amygdaloids, further on by the greenstone and ashbed; towards the lake shore alternating traps and conglomerates are found. At the footwall of the Allouez conglomerate, an amygdaloid lies, the thickness of which is not known, which is also the case with the other formations, accurate surveys and geological researches of this district having, as I was informed, never been made. About 198 meters (650 feet), horizontally measured, from the Allouez conglomerate another amygdaloid bed can be traced, on which the present rockhouse stands, further on a melaphyre is exposed, and then follow the diverse conglomerates, the Calumet, the Kearsarge, and Kingston, which, according to the last geological report, are at about the re-

spective vertical distances of 436.5 meters (1432 feet), 760.8 meters (2496 feet), and 882.7 meters (2896 feet) from the Allouez conglomerate. The Allouez conglomerate in the mine is 12.8 meters (42 feet), measured horizontally across, or 7.92 meters (26 feet) on the perpendicular. As all the beds make a sweep towards the northeast, partially following the curvature of the lake, the Allouez conglomerate is found again at the Central Mine, having a thickness of from 4.57 to 6.1 meters (15 to 20 feet), while near the Phœnix it is replaced by a layer of soft red clay, locally called the "slide," of several centimeters in thickness. This same character has been observed in the Allouez Mines in the winze north of No. I shaft in the crossing. Here is found a red clay having preserved yet the structure of a conglomerate, showing the thorough decomposition. The conglomerate in the mine is variable in character. At the footwall it is a very coarse puddingstone, the portion following this a quartzose porphyry with a variable amount of pebbles. At about the middle of the bed the conglomerate is of a very fine structure, resembling a sandstone. This is locally called the "sandslip;" it is variable in thickness, changing from 7 to 30 cm. (3 to 12 inches), being on an average probably 7 to 10 cm. (3 to 4 inches). Beyond this sandslip little or nothing is known, the hanging wall having only once been struck in the second level, and a drift run along it for a short distance, proving the rock at that point similar in character to the portion to which active exploration is limited.

A longitudinal section of the mine and its workings up to August 1st, 1876, is shown on Plate XI. Three shafts and one winze have been sunk on the bed. Shafts No. I and No. II are those by which work is pushed. No. III has been abandoned at present, and is full of water. The drawing shows two crossings, the one north of No. I winze dipping south, the other south of No. I shaft dipping north; they dip at about 65° towards each other. The crossings are marked by a great deal of broken ground, and have disturbed the surrounding rock materially, keeping the ground poor in copper. Since my return from the lake I have learned that crossing *a* has partly gone down the winze between the fifth and sixth levels, and then jumped off its regular course; that crossing *b* has been lost entirely. On the fourth level a fissure (not shown on the section) appeared, which was being struck at the time on the sixth level by shaft No. I. On the hanging wall of this fissure some of the richest rock of the mine has been struck. The ground around No. II shaft was at the time the most promising part of the mine. Here

the copper is coarser than in any other part of the mine, the general character of the copper impregnations being decidedly fine-grained. The richness of the rock in copper is very changeable, and it requires great discretion and experience to decide which portions to leave in the mine and which to take out. The average yield during the previous year, ending July 1st, 1876, according to the annual report, was 0.87 per cent. of ingot copper referred to the quantity of rock broken and hoisted, or 1.4 per cent. referred to the quantity of rock sent to the stamp-mill. The total quantity of rock hoisted during that year was 82,410 tons, and the quantity sent to the stamp-mill was 51,135 tons, showing that at this mine only 62 per cent. of the total quantity of rock broken is sent to the mill for crushing and washing. The Quincy Company stamped and washed nearly 75 per cent. of the rock mined during the year 1876. The percentage of rock of the Atlantic Mine, working on an amygdaloid belt, was given to me as 1.3 per cent. of mineral, or 0.99 per cent. of copper ingot per ton of rock. At the Copperfalls Mine they work on the ashbed (presumably the same belt as the one on which the Atlantic Mine works), on a rock averaging below 1 per cent. of ingot referred to the quantity of rock stamped. The Calumet and Hecla Mine averaged during the year 1875 to 1876 4⅝ per cent. of ingot copper.

The rock as it comes out of the mine is in variable sizes. The smaller rocks are screened. The larger rocks vary all the way up to 61 to 76 cm. (24 or 30 inches). These in case of the Calumet and Hecla are broken by a steam-hammer, which does the work admirably. At the Allouez and other mines they are blockholed. The steam-hammer saves the wages of 12 blockholers per day for a mine of the Allouez capacity. The rock-breakers in use at Lake Superior are the Blake crushers, the No. 9 and No. 7 the coarse or preliminary breakers, and the No. 5 and No. 4 the finishers, which reduce the rock to the proper size for feeding under the stamps. Generally for one No. 9 or No. 7 two No. 5 or No. 4 are found in use.

The stamp-mills at Lake Superior are very often located at a considerable distance from the mines. The Calumet and Hecla have their mills situated at Torch Lake, and the mine is connected with the mill by a good railroad about 13 kilometers (8 miles) long, the latter end of the route terminating in a well-laid-out automatic inclined plane. The Atlantic mill is situated at Portage Lake, about 4.8 kilometers (3 miles) from the mine. Southeast of this is the Osceola mill, about 13 to 14.5 kilometers (8 to 9 miles) distant from the mine. Then follow along the shore of Portage Lake the Quincy mill, the

Pewabic, and the Franklin mills. The latter three have the advantage of being closely connected with their respective mines by automatic inclined planes. The Allouez mill is connected with the mine by a railroad about 3.6 kilometers ($2\frac{1}{4}$ miles) long; it is situated in section 30, away from water. It draws its water supply mainly from Gratiot River by a system of launders, 71 by 40 cm. (28×16 inches) deep and 4 kilometers ($2\frac{1}{2}$ miles) long. A smaller supply is taken from a dam built about 1.2 kilometers ($\frac{3}{4}$ of a mile) south of the mill, intercepting smaller streams.

The system of ore dressing at Lake Superior in its main points is alike in all the mills, and a description of one mill in its principle will illustrate the mode now in use in these so famous copper districts. Small variations certainly are found in going from one mill to another, to enumerate all of which would lead too far in this paper.

The stamp-mill houses have the rock-bins on the back part of the building, in which variable amounts of rock can be received according to the capacity of the mill; for instance, Calumet and Hecla, 2500 tons; Atlantic, 1000 tons; Allouez, 450 tons, etc. The bottom of the bin has such a slant as to make the rock run towards the charging floor, whence the feeders shovel it into the mortar of the stamps. This charging floor is always the second story of the mill building. In the building there are always three, sometimes four, floors, one of which is used as a machine shop—a necessary adjunct to a Lake Superior mill.

The stamps in use at Lake Superior are the Ball stamps, the Atmospheric stamp at the Phœnix mill, already described by Mr. John F. Blandy in the second volume of the *Transactions*, and the common Cornish stamp used at the Quincy and Central mills. Some of the older and smaller mills, now nearly all shut down, patronized the Gates stamp.

The foundation of a large Ball stamp is mainly made in the following way: A pit is dug 3.65 meters (12 feet) deep, around which a wall is built, which is from 0.9 to 1.21 meter (3 to 4 feet) thick. The section of the pit is 4.25 to 4.86 meters (14×16 feet) inside of the walls just mentioned. On the bottom of the pit a heavy anchor-piece is laid, say 3 tons in weight. The pit is filled by courses of timber, each row alternating in direction. Through these timbers iron bolts pass which hold the anchor-plate in its position. When one of these long bolts breaks, a log screw is made, which is a bolt with a rough wood screw cut on it; this is then put in its place. The joints of all the timbers are cemented tight up to the top, each

bed of timber being cemented as it is put in. A space of 25 millimeters (1 inch) is left between the timbers and the walls all around, which space is not filled out till all the timbers are in. Two cast-iron sills, B B (see cuts on Plate XI), are bolted on to these timbers. These sills have a broad base, and they are made firmer yet by attached knee-braces. On these rest the seven spring-timbers, D D, so that their ends have a bearing on the top of the iron sills. Outside of the two extreme spring-timbers, D D, two wooden sills, C C, pass, laid across the iron sills, B B, and secured to them by bolts. The spring-timbers are 407×457 millimeters (16 inches deep by 14 inches) wide. The bed-plate rests on these, and on it the mortar. Spring-timbers last generally from 10 to 12 months. Along the mortar, in the longitudinal direction of the stamp, are two wooden sills, E E, which rest upon and across C C, and support the two vertical posts, F F, of the stamp frame, to which the principal part of the work is bolted. These posts, F F, are held in an upright position by the iron braces, G G. G is the bed-plate arranged between the sills, E E, and across, and having its bearings upon the spring-timbers, D D, etc. Upon the centre of the bed-plate, G, stands the mortar, H, which is held in position by guides on its sides, which work in the ways, A A, on the front of the posts, F F, allowing a free movement of the mortar in a vertical line, at each blow of the stamp, by the elasticity of the spring-timbers, avoiding the severe jar and wear which would otherwise come upon the machine. The lower portion of the mortar, H, is circular in form, the upper portion being oblong, with a flat top and vertical sides. On the front and back sides are inclined openings for receiving the screens.

A mortar holds, as principal interior parts, first the die; second, the ring; third, the stave linings; fourth, the side linings (of the latter, upper and lower ones are distinguished); and fifth, the frames holding the grates. Fig. 3, Plate XI, shows a horizontal section along the top of the mortar of one of the second-size stamps. It shows the side linings, the front and back screens. The front screens at Lake Superior are inclined from off the mortar as well as from the perpendicular, instead of as in the original Ball stamps. Fig. 3, a, shows an elevation of the side linings, the upper and lower ones respectively. The side linings at the Atlantic mill are made of 12 mm. ($\frac{1}{2}$ inch) wrought iron, at the Allouez mill of 25 mm. (1 inch) chilled cast iron, at the Calumet and Hecla mills the upper side linings are of wrought iron, the lower side linings of chilled cast iron. There are two upper and two lower side liners in a mortar;

their height is 0.533 and 0.484 meter (21 and 19 inches) respectively, and their weight is about 454 kilos. (1000 lbs.) for all four of a No. 2 size stamp. The data with regard to how long they wear without repairs vary at the different localities, being for the upper side liners, 1 year at the Atlantic, 8 months at the Allouez, and 6 months at the Calumet and Hecla. The lower ones generally last one-half that time. The die, as shown, Figs. 7 and 7*a*, is 577 mm. (22½ inches) in diameter on the wide side, and 508 mm. (20 inches) on the other. It is 178 mm. (7 inches) thick, and has on the sides 3 semicircular slots, which descend so as to be nearly cut out at the bottom. They are there to fasten the die. A die of this size weighs about 317 kilos. (700 lb.). The metal ring shown, Figs. 5 and 5*a*, fits the die exactly. In the outer ring are 3 slots, 76mm. (3 inches) long and 45 mm. (1¾ inch) wide, made for the purpose of taking the ring out of the mortar. The ring weighs about 113 kilos. (250 lb.).

The stave-liners, which are shown in Figs. 6, 6*a*, and 6*b*, are made in sets of 7 or 9, or even more, and fit the flange of the metal ring 5*a*. Not all of the stave-liners are of the same dimensions, which vary according to the number used to complete the circle. Their their total height is 432 mm. (17 inches). The stave-liners weigh about 680 kilos. (1500 lb.). The last stave-liner has a hole in it, through which a bolt passes to press the other liners in their places. The die, ring, and stave-liners last about 18 months. Above these are the side-liners, previously described, standing vertically. In front of the mortar are two frames, shown in Figs. 4, 4*a*, Fig. 3, and opposite sketch. A frame holds two screens 1.194 m. (47 inches) high, 0.914 m. (36 inches) wide at the top, and 0.610 m. (24 inches) wide at the bottom. The side timbers of the frame are 76 mm. (3 inches) wide by 76 mm. (3 inches) thick, and the distance between them on the wide side is 0.965 m. (38 inches). These stand out 152 mm. (6 inches) higher than the screens, and they are covered with 3 mm. (⅛ inch) sheet iron. The frames are inclined, to prevent any particles or pieces of rock from being thrown through them, they being easier deflected by means of the inclined surface. In the centre and at the top is a hole which enables the workman to pull the screen out of the side guides of the mortar by means of a hook and blocks. The two screens hold between each other four grates of sheet steel, which have, in the case of the Allouez mill, holes of 3.7 mm. (⅛ inch) in diameter, 3.7 mm. (⅛ inch) apart in the horizontal direction, and 4.5 mm. ($\frac{3}{16}$ inch) apart in the downward

direction. These grate-holes are punched in the mill machine shop. The back screens are similar to the front screens, being only of a rectangular form instead of trapezoidal shape. There is only one back screen holding four grates of equal size. These screens have to be pulled out and replaced every time when a new shoe is put on to the stamp shaft, aside from when the grates need replacing. The back and front grates wear about alike. When the back screen wears, it commences at the bottom; it is then taken out, turned upside down, and put into the front screen. The front and back grates last about three weeks at all the mills. Of the front grates the two outer ones last longer than the two inner ones.

Of the screens which hold the grates, the one next to the mortar lasts about three months, and the outer one from 18 to 24 months. At the Atlantic they observed quite a large amount of oblong-shaped copper in the mortar, which refused to pass the round holes of the grates. The grate-holes here, as also at all the other mills, are 4.8 mm. ($\frac{3}{16}$ inch) in diameter, excepting the Allouez mill, where they are, as mentioned before, 3.2 mm. ($\frac{1}{8}$ of an inch) in diameter. To obviate the troublesome oblong copper, they substituted successfully for two grates with round holes of 4.8 mm. ($\frac{3}{16}$ inch), two with oblong ones of the size 3.2 mm. $\times$ 12.7 mm. ($\frac{1}{8}$ inch $\times$ $\frac{1}{2}$ inch). At the Atlantic mill each screen holds since then two grates with round holes, the two outside ones, and two with oblong holes, the inner ones. Such a grate, with $\frac{3}{16}$ inch holes, has in all about 22,000 holes, and one-half this number of oblong ones. The steel grates when worn out are utilized as linings in the wooden launders. They use No. 12 steel plate. The next important part in the mortar is the shoe. It is shown in Fig. 8. The weight of the larger-sized shoe is 285 kilos. (630 lbs.), fastened to a 203 mm. (8 inch) stamp-shaft, while the weight of the second size shoe is 185 to 195 kilos. (400 to 430 lbs.), with a 178 mm. (7 inch) stamp-shaft. At the Calumet and Hecla, Allouez, Pewabic, etc., mills, the material of the shoe is a mixture of chilled white and gray iron; at the Atlantic mill they use a hardened cast iron mixed with some Franklin spiegel. They claim that it does not wear round, while the chilled iron does. The shoes of the Calumet and Hecla last about 5 to $5\frac{1}{2}$ days; at the Allouez the same, probably a trifle more. The shoes of the Atlantic can be used for three weeks, which is mainly due to the softer amygdaloid which they stamp. The shoe is connected with the stamp-stem by a dovetail joint. One side of the dovetail, instead of being straight like the other or that against which the wedge-key is forced,

is made curved to the arc of a circle. The lower part of the shoe is made so as to have a larger stamping surface on one side of the vertical axis of the rod than there is on the other. This, as the stamp rotates, causes the stamp to continually strike in a fresh place on the ore, and prevents it from packing in the mortar. A stamp-stem can generally be used for two years. On the top of the mortar is a water-urn, into which water is admitted through two 51 mm. (2 inch) pipes, under the head of a 1.524 m. (5 feet) reservoir. The shute through which the mortar is fed is shown in Fig. 9; it is fastened to the shute cap-holder along *a b*. The cap is shown in Fig. 10; it slides into the guides of the cap-holders, and both with the shute are inserted in the iron frame shown in Figs. 12, 13, 14, and 15. This frame is bolted to the mortar and provided on its top with a sheet-iron hood, L. The shute is placed on the back part of the mortar over the back screens.

The wrought-iron stamp-shaft works in the boxes, O O (see elevation, Plate XI), and between these boxes and about the shaft is a revolving clamp and pulley, Q, having feathers which work in splines in the stamp-shaft, P, and by means of a belt on the pulley a rotary motion is given to the stamp-shaft during its upward and downward motion. T T are cheekpieces to which the steam-cylinder, S, is bolted. On Lake Superior, where the stamp is operated by direct action of steam to the stamp-shaft, a bell is allowed to ring when the stamp has descended to a certain point, so that the feeder may replenish the mortar with ore. Should he neglect to attend to his duty, and the stamp continues to descend, the lower head of the cylinder would be knocked out if the common straight steam-cylinders were used. Mr. Ball has therefore adopted the device shown in Fig. 1. At *m* the diameter of the cylinder is enlarged, so that, the piston arriving at that point, the steam passes freely round it, and the operation is immediately stopped. When steam is admitted both above and below the piston, it is evident that the piston will descend much more rapidly than it ascends, and consequently that the valve should remain open a longer time for the admission of steam beneath the piston than is required when the steam is passing above the piston. This irregular valve motion is given by the two elliptical eccentric gears, *b* and *b*', the former being driven upon the driving-shaft, *d*, and the latter upon the shaft of the eccentric which operates the valve-rod, *z*. I give as a matter of interest a steam chart prepared at the Atlantic mill in 1868. (See Plate XI.) Boiler pressure was 87 pounds, and the stamp made 80 strokes per minute. Length of stroke was 0.635 meter (25

inches). No. 1 stamp, 0.305 meter (12 inches) cylinder, 120 tons of ore per day.

The valve is operated by a separate machine, which runs also the washing machines, turns the stamp-shaft, runs the lathes, etc.

Fig. 2 shows the connection between the upper part of the stamp-shaft and the piston-rod, *p*, of the steam-cylinder, S. It is made by means of a circular head, *f*, fixed on the rod, *p*, and inserted into a cylindrical cavity, *g*, formed down in the upper end of the stamper. Under and above the head, *f*, is an india-rubber or other proper spring, *h* or *i*, the whole being covered by a plate, *k*, which is confined to the top of the stamper by screws. The piston-rod, *p*, passes from the steam-cylinder downward through the centre of the bunter-beam, *v*, and to the stamp-shaft bonnet, *f*. The bunter-beam, *v*, contains a cushion against which the top of the stamp-shaft bonnet, *f*, would strike should the stamp-shaft lift too high, arresting it in its upward motion and preventing the piston from knocking the cylinder head out.

A steam-cylinder at the Calumet and Hecla is rebored about every two years, at the Allouez and Atlantic every year. The piston and piston-rod wear about the same time. A cylinder is rebored no more than three times. Sunday is taken throughout the district as a day for repairs. To put a new shoe on takes about 35 to 50 minutes, to change the mortar about four hours.

I annex a table giving the stroke, diameter of cylinder, number of blows per minute, etc., etc.:

No. of Stamp.	Diameter of Shaft or Stem, in millimeters and inches	Weight of Stamp-shaft and Shoe, in kilos and pounds.	Extreme Stroke or Lift, in millimeters and inches.	Diam. of Steam-cylinder, in millimeters and inches.	No. of blows per minute.	Horse-power required for 1 head.	Actual amount rock crushed per day of 24 hours.
	mm in.	kilos. lb	mm. in.	mm. in			
1 . .	203 (8)	2040 (4500)	712 (28)	305 to 381 (12 to 15)	90	60	120
2 . .	178 (7)	1587 (3500)	712 (28)	279 (11)	90	52	96
3 . .	152 (6)	1134 (2500)	661 (26)	229 (9)	95	35	65
4 .	127 (5)	680 (1500)	610 (24)	203 (8)	110	16	35
5 . .	102 (4)	295 (650)	457 (18)	152 (6)	120	8	15 to 20

At the Calumet and Hecla mills they have 7 of the largest size heads, of which one is kept as a reserve head. At the Franklin mill they have 4 of the second size stamps, at the Allouez 2 of the small size. At the Atlantic 4 of the largest size, of which 1 is kept as a reserve head. At this mill they found that by keeping 1 reserve head for accidents, and running 3 heads constantly, they were able to produce 4 per cent. more copper in the long run than when running 4 without a reserve head.

The crushed ore runs through the discharge hoppers, L L, into a launder, which empties the material into the hydraulic separator. The run of this launder varies from 167 to 273 mm. per meter (2 to $2\frac{1}{2}$ inches per foot).

The separator is shown in the plan and section, Figs. 16 A and 16 B. It is a triangular-shaped trough of from 3.658 to 4.572 meters (12 to 15 feet) long, 0.838 meter ($2\frac{3}{4}$ feet) broad on the top or the base of the triangle, and 0.610 meter (2 feet) deep inside. There is a trough within a trough, the space between the two being from 63 mm. to 88 mm. ($2\frac{1}{2}$ to $3\frac{1}{2}$ inches). This interspace is divided into four compartments of unequal size, say 0.560 meter, 1.270 meter, 1.219 meter, and 0.813 meter (22, 50, 48, and 32 inches), or similar, which compartments go part of the way down the sides. Into these water is admitted by two 38 mm. ($1\frac{1}{2}$ inch) pipes, the one pipe supplying the water for the first division, the other one supplying the remaining three. The inner trough has a narrow slot cut in its bottom, which puts it into communication with the outer trough. On one end of the separator is a receiving-box for the crushed ore. In this separator 4 different sizes of ore are the result of the action of the underwater and the water which enters with the ore. The water leaving the separator is conducted to the slime collecting-boxes. An opening is made on the one side and near the bottom of the separator at four different points, large enough to admit a perforated stopper, through which the ore escapes on to the aprons of the jigging machines, which stand in front and below the separator; see Fig. 17. The size of the grain of these four classes will be more apparent when the sieves of the jiggers are described. Generally two such separators are calculated for one head. At the Atlantic mill they have $2\frac{3}{8}$ separators to one head of the larger size.

The aprons of the jigs are of trapezoidal shape (see plan, Fig. 16). The jigs in use are the "Collom Washers," called by the name of the inventor, Mr. John Collom.

A jig consists in the main of a wooden framing, *a a*, having fitted in it two cisterns, *b b*, which are made with inclined sides, as shown in Fig. 18, 1 and 2. Each cistern, *b*, is provided with a discharge-opening in its bottom, and in these openings hollow plugs are inserted. At the upper part of each of the cisterns, *b b*, a horizontal sieve is fitted, not shown in the figure. In the space between the two cisterns, *b b*, is placed a vessel or box, *f*, divided into equal compartments, *f f*,[1] by a bar, *g*. These compartments communicate with the cisterns, *b b*,[1] by openings in their bottoms. In each of the com-

partments, $f\,f^1$, there is a plunger, $i\,i^1$, to which plungers are attached the vertical rods of, $j\,j^1$, which pass up through the guides. The upper parts of the rods, $j\,j^1$, are surrounded with coiled springs which rest on the guides, k. Each one of the rods, j, has a collar, j^2, upon it, against which the upper end of the coiled spring bears, and on each rod above the collar, j^2, there is a thimble, l, shown in Fig. 18, 3, which is screwed on to the rod and is held in place by a set screw, j^3. The upper surfaces of the thimbles have recesses made in them to receive pieces of india-rubber. A rocking bar or lever, m, is mounted on the axle, the journals or trunnions of which are fitted to work in bearings. This rocking bar carries at the upper end an arm, which passes through and works in a brass carried by a crank of the driving shaft, so that by the rotation of the crank-shaft the bar or lever, m, will be made to rock upon its axis, and by so doing the opposite ends of the lever will be alternately brought down on to one or the other of the thimbles, l, at the top of the plunger rods, j, and thus depress the latter. The length of the stroke of the pistons or plungers, $i\,i^1$, may be varied as desired by raising or lowering the thimbles, l, at the top of the piston-rods, and turning the adjusting-screws, $n\,n^1$, which pass through the holes in the guides, k, and are capable of being raised or lowered as may be desired for the purpose of arresting the upward motion of the plunger, $i\,i^1$.

Screwing the adjusting-screws, $n\,n^1$, up or down will also have the effect of regulating the tension of the coiled springs. It will be seen that the rocking-bar or lever, m, has a certain extent of motion, which does not affect the plungers and their rods, which are only actuated when the end of the lever, m, comes in contact with and depresses them. It will be evident, therefore, that by screwing up or down the thimbles, l, and also the adjusting screws, n, the extent of motion of the plungers may be regulated at pleasure. The coiled springs around the rods, $j\,j^1$, are designed to raise the plunger, $i\,i^1$, after they have been depressed or forced down by the action of the rocking-bar in the manner described. At the lake two sets of machines have their rockers connected.

There being two compartments, $b\,b$, two kinds of ore, differing in quality, size, grain, or specific gravity, may be washed simultaneously without becoming mixed. In washing it is often found that the metallic particles are thin and light. To prevent any floating off of this material thin crossbars are sometimes laid across the screen, the lower edges of which sink a little below the edges of the pulp, to retain the fine ore long enough to enable it to sink into the

mass and be saved. The underwater is given to each jig separately by a 25 mm. (1 inch) pipe under a head of a 1.524 meter (5 feet) reservoir. It is regulated by a valve outside of the jig.

The coarse jig-sieves last about six months, the finer ones one year; they are made of brass wire. The number of pulsations of such a jig-plunger are 120 per minute.

The material after having been washed on several jigs, passes into the settling-box S. These are substantially rectangular boxes divided into two compartments, a smaller one and one about twice as large. The sides of these boxes, in the direction of the longer axis, have a stand towards the bottom. The section made larger is intended to catch the finer sands from the 25 sieves against the smaller section intended for the coarser sands from 16 sieves. Such a box is shown in section in Fig. 19.

The next machine of interest is the rotating-table, above which are the common collecting-boxes, which need no description. The rotating-table receives the fine slimes which the water on leaving the hydraulic separator carries along. The table is shown on Fig. 20 in elevation and vertical section. It is essentially the old convex table, but has, all over the lake, Mr. Evans's patent apron, *p*, attached to it: this is stationary. *a* is a vertical axis, having a bevelled wheel at its upper end, gearing with a similar one on the horizontal shaft, *b*. It is driven at such a speed as to revolve the table from 1¼ to 1½ times per minute. To the axis, *a*, a number of wooden arms, *c*, are attached, sloping from the centre. They are radially supported by wooden arms, *d*. The wooden arms, *c*, are covered with planed planks, *e*. The inclination of the table proper is 5° 39′. The diameter at the edge of the table is 5.486 meters (18 feet) exclusively of the waste-launders, etc. Pipe *k* supplies the feed-water to a cylindrical receiver, *g*, shown broken in the elevation. This receiver has, at its bottom, holes for the emission of the water and slimes. The slime entering this receiver is uniformly distributed over the apron. A pipe, *k*, carries water into its branches, *i* and *h*, which are both perforated with holes, to wash the table in thin streams. As the table revolves, the ore upon it, subjected to the action of water, is carried a greater or less distance down to the table, according to its specific gravity. The lightest is washed into the waste launders, *f f*; the medium quality at the edge is washed after a complete revolution into the middle head-box by means of the spouts at *h*, and the launder, *l*. The richest slimes are washed by

the jets, *i*, into the launder, *m*, and through it into the box marked copper box.

Outside of these machines the mill contains a keeve and a buddle. The keeve is shown in outline, Fig. 21. It is 1.168 by 1.066 meter (3 ft. 10 in. by 3 ft. 6 in.) in diameter on the upper side, and 0.661 meter (2 ft. 2 in.) on the lower side. It is 0.965 meter (3 ft. 2 in.) high. In its centre stands a movable axle, *a*, resting at the bottom on a pivot. Near the bottom are cross-arms, *b*, and on its top is a handle. The buddle shown in the plan is a rectangular box about 3.658 meters (12 ft.) long, by 1.119 meter (44 inches) across. It has an apron about 0.762 meter (2½ ft.) long with a hopper or distributing-box 0.559 by 0.457 meter (22 in. by 18 in.) on the top. The apron has six distributing-blocks 76×51 mm. (3×2 in.) on each side (see plan of tail-house). The end of the buddle has ten holes, 38 mm. (1½ in.) in diameter, 51 mm. (2 in.) apart, to enable the drawing off of water. The slant of the buddle floor is 10.8 mm. per meter (⅛ of an inch to the foot). At about a distance of 0.457 meter (18 in.) from the head of the buddle the water is admitted from below. The head of the buddle stands about 0.610 meter (2 feet) from the ground. All the wood used is 51 mm. (2 in.) thick. So much for the description of the machines in use.

The mode of dressing the copper is nearly alike through the whole district. The following is a description of the mode in use at the Allouez mill: The material after being stamped by the Ball stamp runs through launders to the hydraulic separators. Here four different sizes of ore result; the 5th one, the slimes, are carried by launders from the separator along the sides of the building to the slime-collecting boxes. The plan has 4 hydraulic separators, each separator having 7 machines with 2 sieves; hence there are 28 machines or 56 jigs in the building. As the arrangement for each quarter division of the mill is the same, it suffices to describe a quarter section to have the mode of working of the whole mill. The plan, Fig. 16, *A*, shows the jigs with the respective numbers 10, 12, 16, 25, and again 12, 16, 20, 30, etc., marked on them. These numbers designate the fineness of the wire sieves, being $10 \times 10 = 100$ or $12 \times 12 = 144$, etc., rectangular meshes to a space 25 by 25 mm. (1 square inch). To abbreviate, I will call such sieves the 10, the 12, 16, etc., sieves. Between two sieves the letter *M* is marked, designating the machine with framework, between which the rocking levers, stems, plungers, etc., previously described, work. Two of such adjoining sieves form one machine, as shown on Fig. 18. An

entire machine is 2.063 meters (6 feet 10 inches) wide, 1.068 meter (3 feet 6 inches) long, and 0.838 meter (33 inches) high on one end, and 0.965 meter (38 inches) high on the other, owing to the slant of the flooring. The jigs in the first row, reckoned horizontally, are called the "head-machines;" in the second row, the "first tail-sieves;" in the third row, the "finishers;" in the fourth row, the "tail-finishers;" in the fifth row, the "second tail-sieves."

From the horizontal separators the ore drops through perforated stoppers, Fig. 17, on the aprons, A, of the respective 10, 12, 16, and 25 sieves. At this stage I will state that the final products of the Allouez mill are a No. 2, a No. 3, and a No. 4 copper, varying in purity and size of grain. No. 1 copper consists of the chunks of metallic copper pounded together in the mortar, which are collected till a barrelful is obtained—one barrel per two months. Returning to the top sieves, where the material has been received on the aprons, it runs down those on to the 10, 12, 16, and 25 sieves; here it is jigged; the lighter material goes to the top, is washed down the aprons connecting the first with the second row, or the head-machines with the first tail-sieves; here it is rejigged.

What runs through the 10 sieves is No. 3 copper; it is conducted by launders at the bottom of the machines along the floor to the aprons of the 16 sieves, in the third row—the finishers. The top rock of the 10 sieves is taken off, about 1 pailful each time, and it is put back under the stamp, being very coarse; the copper below it is No. 2 copper. The sieve is cleaned about four times a shift (12 hours); ¾ of a pailful of No. 2 copper is taken from it each time and put into the copper barrels. The material running off from these 10 sieves runs to the 12 sieves of the first tail-sieves, or the second row. It is rejigged here. The quantity that runs off here runs into the launders, *L*, and is carried on to the beach. What runs through the 12 of the first tail-sieves runs to the 16 sieves in the fourth row—the tail-finishers. It is of No. 4 grade. The quantity remaining on the 12 sieve is skimmed about four times per shift, taking each time about a pailful. It is put back under the stamp. The next sieve, the 12 of the head-machines, works exactly like the 10 sieve just described, and so does the 16 sieve in the second row, or the first tail-sieves, work similarly to the 12 sieve described of that row. The products of both are united and go to the same finishing-sieve. In fact, the entire head-machines work all alike, only they run in couples of two. The products of the first two are kept together, and the products of the last two likewise.

10 and 12 form one couple, and 16 and 25 the other. The part going through the 16 and 25 sieves of the head-machines goes to the 25 sieves of the finishing-machines, or third row. The part going through the 20 and 30 sieves, second row, or the first tail-sieves, goes to the 30 sieve in the fourth row—the tail-finishers. Sieve No. 25, head-machines or first row, is skimmed only once a week. To resume briefly: The head-machines furnish the copper No. 2. The first tail-sieves to the head-machines have the material on the sieve restamped. The quantity running through the sieves of the head-machines is finished in the third row, on the finishing-sieves. Again, the material running through the first tail-sieves is finished in the fourth row, on the tail-finishers. Coming to the third row, the finishers to the head-machines, we find no rock for skimming on the 16 as well as 25 sieves of this row. On both sieves No. 3 copper is produced. The 16 sieve is skimmed 6 times per shift, and 6 pailfuls of copper are taken. The 25 sieve of this series gives only 1 pailful of copper per shift. The material running through the 16 finishing sieve is No. 3 copper; it is washed in the box marked 3, standing in front of the fourth row. What runs over the 16 finishers runs on to the 16 tail-finishers, fourth row, and unites with what came from 10 and 12 of the first tail-sieves. What remains on the 16 tail finishing-sieves is skimmed once per shift, yielding 1 pailful of skimmings, which are brought back under the stamps again. They collect about 1 pailful of No. 4 copper per week on this sieve. That running through this sieve is No. 4 copper; it is washed in the box next to the No. 3 copper.

The finer sieves 25 and 30, third and fourth row, work in a like manner. The material running through the finishing 25 sieve is No. 4 copper, and so is also what runs through the tail-finisher 30. Both are run into wash-boxes marked 4. The No. 4 copper of the 30 sieve must still be keeved. The material accumulating on the 30 sieve is skimmed once in 12 hours, 1 pailful at the time. It is re-stamped. All the material running off of the tail-finishers, the 16 and 30, is run into the box S, which has the inclined sides before mentioned. The 16 enters the smaller compartment, the 30 sands the larger one. From these boxes the material runs on to the second tail-sieves, the 20 and 30 respectively. What copper remains on this is No. 4 copper. The rock skimmings go back to the stamps, and the material which runs through the sieves is No. 4 copper. It runs into the boxes marked No. 4, in front of the bottom machines. The No. 4 copper from both sources has to be buddled and tossed to

purify it a little more. The rock skimmings of the 20 sieve bottom machines amount to 1 pailful per shift; of the 30 sieves, to only $\frac{1}{2}$ pailful. What runs over the bottom machines runs to the tail-house, uniting with the overflow of the box S. The product of the rotating-table is buddled in the apparatus before described. The material thrown into the head-box or hopper of the buddle is drawn out and worked towards the sides. Water is admitted, and the material well shovelled through and broomed. Water is drawn off, and the material divided into three parts, head, middle, and tail. The tails are run back to the rotating-table, the middle is rebuddled, and the heads are put into the keeve.

The work in the keeve is effected by shovelling the material into it, filling the same half with water, and letting two boys turn the handle of the axle and fan. After about ten minutes the whole is fully well in rotation. It is then tossed and packed with a box, the water is drawn off, and the tub skimmed with a scraper, which is an ordinary hoe with a 0.457 meter (18 inch) handle. The product is divided into three portions. The top, or the lightest, goes back to the round table, the middle is again buddled, and the bottom, the richest material, is retossed. The second top is rebuddled, the second middle is put in the keeve again, and the bottom is put into the barrels as No. 4 copper.

This is essentially the Lake Superior process for dressing. The flooring of the Allouez mill has a slant of 125 mm. per 1 meter ($1\frac{1}{2}$ inch to the foot). Whatever is spilled is washed together, swept, and utilized. In other mills there are separate catch-boxes for this purpose in the flooring of the mill, as at the Calumet and Hecla, Franklin, Atlantic, etc. At the Franklin mill the product of the rotating-table, instead of being buddled and keeved, is conducted by launders to a percussion-table. The table has an apron suspended over its back end; on this the material runs. The lighter rock washes below the apron on the back end of the table into a box. These slimes are retreated on the rotating-table; the richer material advances forward on the table, and is washed off into the copper box by a thin stream of water emitted from a triangular-shaped sheet-iron box. The table is the common percussion-table suspended on 4 iron arms, movable in the direction of the stroke. The stroke is given by 3 cams, fastened to an axle, striking on a piece of flat iron fastened below the table.

The jar of the back stroke is eased by letting the table strike a spring, coiled round a stem, similar to that in the Collom washer.

This washed material is then keeved. The same table is at the Calumet and Hecla mills. The stroke in those mills is given by the elliptical gear of the Ball stamp. Such table makes 150 to 160 strokes per minute.

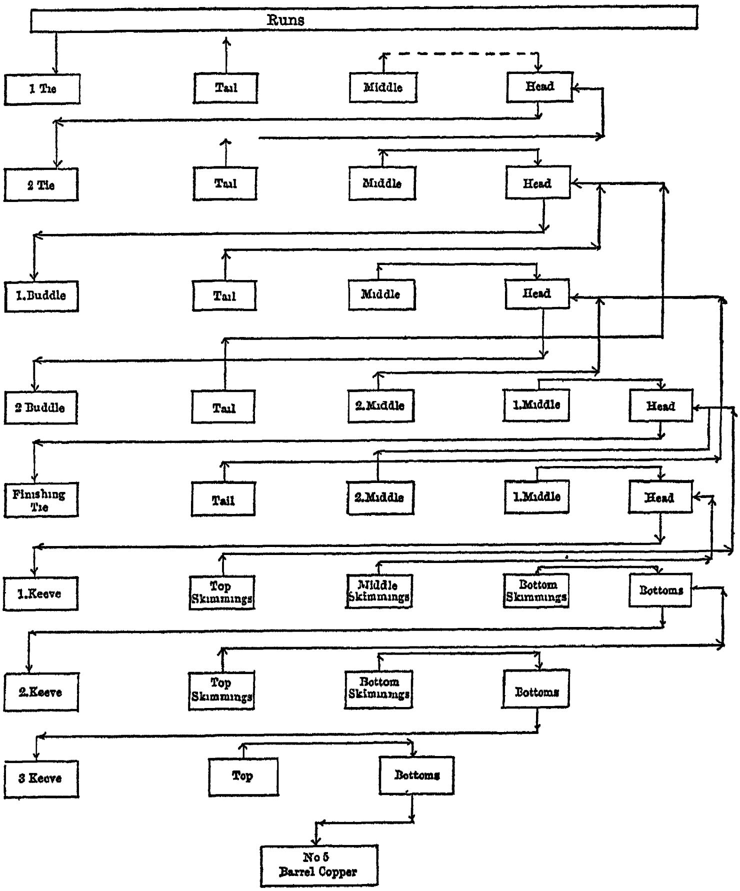
At the Atlantic the product of the rotating-table is finished on a second rotating-table, and the product of the second table is keeved, while the tailings of the second table are worked over again on the first rotating-table. Another favorable feature of the Atlantic mill is that the products of two different sieves are never mixed. The product of a 10 sieve is never mixed with the product of a 12 sieve, as they do at the Allouez, where the 10 and 12 go to the 16 sieves. They use at the Atlantic sieves with 64 meshes up to sieves with 1225 meshes to a space 25×25 mm. (1 square inch), against the 100 up to 900 mesh sieves of the other mills. Turning again to the mill plan, we see that the tailings from the bottom machines, the rotating-tables, the overflow of the box S, and the slime-collecting boxes go to the tail-houses, which are shown below the mill plan, Fig. 16, *A*.

In the tail-house, *a* is a launder connecting with the launders from the top machines; *b* is the launder carrying the tailings from the bottom machines, rotating-tables, etc.; *c* is the clean water head-box; *d* is the head-box of tailings; *e* is a keeve; *f* and *g* are the tailing-runs; *l* is a run for the buddle and ties; *k* are the ties; *h* is a buddle; *i* is a finishing-tie; *n*, a trough leading to the ties. All the machines, except the ties, have been described. A tie is a square box 3.2 meters (12½ feet) long, 1.066 meter (42 inches) wide, and 0.762 meter (30 inches) high. It has on one end a distributing-board, 0.305 to 0.356 meter (12 inches to 14 inches) long, running across the table. Its slant is 61 mm. per meter (¾ inch to 1 foot). The ties are connected with the trough, *n*.

In the tail-house the tailings are allowed to fill the runs, *f* and *g*; it is so managed that *f* is full when *g* is empty, and *vice versa*. The tailings are thrown into the trough, *n*, from out of the runs. The trough, *n*, is a sort of separator with a channel allowing the water to flow out of it. The tailings are worked through in the trough, *n*, by boys, and are then thrown on the ties. When the tie is full, the trough is empty. The tie is divided into three parts, head, middle, and tail. The mode of working the tail-house is best shown by the annexed tree.

The size of the heads, tails, etc., cut out, varies with the richness of the material, which is ascertained by taking a sample and vanning it on the shovel. To ascertain how to cut, the heads and tails are

always vanned. When the material is rich, a long head and a short tail is taken; when poor, on the contrary, a short head and a long tail is taken. Heads are allowed to accumulate till there is enough to work a tie; the same is the case with the buddle. It will be seen



from the tree that over 50 operations are necessary to produce the No. 5 copper. This averages from 35 to 40 per cent. copper. Two barrels weighing each about 1300 pounds, are produced per month. The ties are worked daily, the buddle 20 days, the finishing-ties 2 days in the week, and the keeve only once a week. Cast-off stamp-feeder shovels are used in the tail-house; they serve here still 6 months. Besides 3 of these, a hoe for the keeve and one broom is used. The latter has to be replaced about every 3 weeks.

The products of the mill are 4 grades of "barrel copper," averaging: No. 2, 93 to 94 per cent.; No. 3, 81 to 82 per cent.; No. 4, 41 to 45 per cent.; No. 5, 34 to 40 per cent. At the Atlantic mill they produce 90, 80, 60, 50, and 40 per cent. barrel copper.

The labor account in a mill stamping from 300 to 350 tons, 3 heads running, would be, per 24 hours, with 56 machines:

In the mill:		Spare men cleaning up,	2
Stamp-feeders,	12	In the tail-house:	
Firemen,	8	Man,	1
Engineers,	2	Boys,	5
Machinists, repairing,	2		—
Blacksmith,	1	Total labor in mill,	47
Copper-dressers,	2	" " tail-house,	6
Boys on the wash,	18		

The same for a mill stamping 180 tons, with two heads, per 24 hours and 28 machines:

In the mill:		Boys on wash,	9
Feeders,	6	In tail-house:	
Firemen,	6	Man,	1
Engineers,	2	Boys,	3
Machinists,	2		—
Blacksmith,	1	Total labor in mill,	30
Head-runners,	2	" " tail-house,	4
Copper-dressers,	2		

The losses at Lake Superior in dressing are still large, and are partly due to scaly copper being floated away, partly due to fine copper being contained in the rock which is washed on the beach:

According to assays made at different times:

	Per cent. Cu.		Per cent. Cu.
Tailings from No. 2 and 3 contained	1.32	Tailings from No. 4 contained	0.84
" " " 2, 3, and 4, "	1 21	" " " 5 "	1 36
" " " 2, 3, and 4, "	0 87	" " rotating-table "	0.90
" " " 3 and 4, "	1.03	" " " " "	0.82
" " " 4 "	0.98	" " " " "	0 78

These results were certainly obtained in the wet way, and not by fire assay.*

* The Allouez mill commenced last July the erection of a separate mill of 28 Cornish heads to restamp the coarser sands, their attention having been called to the great losses incurred by letting the coarse sands be washed on the beach. Up to the 1st of January, 1877, not half of the mill was completed, and I have not learned since whether they succeeded in finishing it.

I affix a table showing the economical results of different mills for 1875–76:

Localities.	No. of tons stamped.	Pounds of mineral produced	Per cent. of rock in mineral.	Per cent of rock in ingot.	Average per cent of mineral produced.	Tons of rock stamped per cord wood.	Cost of milling per ton rock.
* Allouez, ...	51,135	1,875,397	1 83	1.40	76 25	5.74	$1 08
* Atlantic, ...	80,000	2,178,897	1.36	0.99	71 92	14 097*g*	0 879
* Franklin, ...	58,942	1,498,120	1 27	0.99	77.915	10 84	0.783
† Central, ...	17,118*f*	2,407,437	3.78	2.68*b*	70.82	10.27*a*	0 8676
† Quincy, ...	70,501	. . . .	. . .	2 44	. . .	12 48	0.965
‡ Phœnix, ...	80,000	2,177,600*c*	1.36	0.979	71 93*d*	. . .	0.8796
* Calumet & Hecla,	. . . .	. . . . .	5 50	4.75	78 50*e*	. . . .	. . .

An inspection of the foregoing table would lead us to give the Ball stamp the preference as to cheapness of treating one ton of ore. The result of the Atlantic mill, though lower than the Quincy already, will show a reduction in the cost of milling and stamping from 1876–1877. I was informed it would be about 70§ cents per ton. The Quincy cost for 1876 was 91 cents per ton. The improving and remodelling which the present managers had to do after taking charge of the mine and mill hardly permits me to take these results as final, and yet the Atlantic mill compares now already favorably with any on the lake. When once old mistakes have been entirely overcome, the Atlantic mill will show how a Ball stamp compares with the old Cornish stamp, circumstances being alike, and I do not hesitate to say that the Ball stamp will prove to be the cheaper one, and in the course of time do away with the Cornish stamp in this district.

Another machine much in use in the tail-houses of Lake Superior

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* = Use Ball stamps.

† = Use Cornish stamps.

‡ = Use atmospheric stamps.

a One head averaged per 24 hours 5 87 tons of rock. 32 heads were running for 91 days.

b Calculated from official figures: $3\ 78 \times 70.82 = 2.68.$

c " " " " $\frac{1.361 \times 80,000}{100} \times 2000 = 2,177,600$

d " " " " $\frac{0\ 979 \times 100}{1.361} = 71.93$

e " " " " $\frac{4\ 75 \times 100}{5.50} = 86.36 =$ instead of 78.50 per cent. The Houghton Gazette gave all three data. 78.50 per cent. is probably correct.

f Mine produced mass copper besides.

g Per ton coal.

§ I find, since writing this, that the cost is only $0.6709.

is the round convex buddle, essentially the same as the one described in Dr. Raymond's *Report West of the Rocky Mountains for* 1873. The report also gives the common percussion-table as well as Rittinger's and Gaetzchmann's *Aufbereitungskunde.* The quantity of water used in dressing is also variable.

The Atlantic mill, with three heads running, stamping on an average 320 tons per 24 hours, and using 56 jigging machines, consumes 8316 liters (2200 gallons) of water per minute. Or, in other words, 41.35 tons of water enter the mill for every ton of rock stamped during 24 hours. At the Allouez mill they use 5882 liters (1556 gallons) of water per minute; they have two heads, and stamp on a good average 180 tons per 24 hours. The number of jigging machines is only 28. Expressed in tons of water, they use 52 tons of water per 24 hours for each ton of rock stamped. This is generally conceded to be too much. A statement which was given to me by the gentleman in charge of the Allouez mill distributes the water in the following way (this statement was prepared last September):

Total quantity of water which enters the mill, 5882 liters (1556 gallons) per minute.

Two heads, each 756 liters (200 gallons), per minute,.	1512 liters	or	400 gallons.	
28 machines or 56 mashers, each 56.7 liters (15 gallons), per minute, ...	3175	"	" 840	"
4 separators, each 226.8 liters (60 gallons), per minute, ...	907	"	" 240	"
2 rotating slime-tables, each 64.26 liters (17 gallons), per minute, ...	129	"	" 34	"
Total, ...	5723	"	" 1514	"
The remaining 159 liters (42 gallons), per minute, are used for the hand-buddle, the tossing-keeve, feeding the boilers, etc., ...	159	"	" 42	"
	5882	"	" 1556	"

I am sorry I am not able to place a detailed statement of the Atlantic mill against this, but I was not able to obtain it. I may say that the impurities in the different grades of barrel copper or mineral—the latter is the expression used at Lake Superior—are, for the grades of No. 2 and No. 3 copper (at the Allouez mill), mainly parts of the common conglomerate gangue which have not been removed. Besides this, however, I observed notable portions of peroxide of iron. The latter is more predominant in the material found on

the tail-finishing sieves of the mill. It is present there to such an extent that I have repeatedly with the naked eye picked out pieces with a pair of pincers. I mention this fact because it is, as a rule, impossible to see any peroxide of iron in the conglomerate rock with the naked eye or even with a glass. Only once I was fortunate enough to find a piece of conglomerate on the filled cars going to the mill, in which I could see two specks of black appearance, which proved to be the peroxide of iron upon testing them in the laboratory. The percentage of the peroxide in the conglomerate must, however, be very small, inasmuch as the quantities which I observed in the mineral were constituents concentrated from a mass of, say, from 150 to $3\frac{1}{2}$ tons. The remaining impurity is metallic iron, derived from the stamp-shoes. This is present to a marked and very large extent in the No. 5 copper which is derived from the tail-house. It occurs here nearly as fine as flour up to thin scales 13 mm. ($\frac{1}{12}$ inch) long. Here also the peroxide is found. I was not able to detect any magnetite in either of the grades of copper.

The mineral at Lake Superior is packed wet into the barrels, and the average percentage of water at the Allouez is:

For No. 2 copper,	. . .	3.00	per cent.	of water	at the mine.
" 3 "	. . .	7 to 7.5	"	"	"
" 4 "	. . .	12	"	"	"
" 5 "	. . .	12 to 13	"	"	"

The only mill to my knowledge which dries its mineral is the Franklin mill, and this on rather a costly apparatus. Why a common drying-floor heated by the exhaust steam is not introduced in this district is more than I am able to say. Drying with the exhaust steam certainly would not cost as much as driving out the water at the cost of smelting the copper. The charge for smelting a ton of mineral is $18, and the charge for driving out a ton of water is the same. The idea prevalent with some persons on the lake of extracting the metallic iron with a magnet, I consider at present impracticable. According to experiments, which I have made to satisfy persons, I found that with every extraction of metallic iron 50 per cent. of the extract was thin metallic copper drawn over with iron. The only thing, in my estimation, which will decrease the quantity of metallic iron in the lower grades of copper, is a larger number of slime-settling boxes, and likewise of rotating-tables. The latter are worked decidedly over their capacity. The tail-houses all over Lake Superior would hardly pay for

the keeping of them, if it was not that they are to some degree a check on the working of the mill proper. I think the time is not so far off as many may think when people will do away with the present mode of working the tail-houses, and when the treatment of tailings will become a special system of dressing at Lake Superior. The Collom jig is decidedly one of the most perfect jigs we have, allowing of such very fine adjustment. The introduction of a larger number of these in the mills could only be beneficial to economical results.

An idea upon which some on the lake may experiment is to give the hydraulic separator a slant of the bottom in its longitudinal direction towards the lower end where the fine sands are collected. This will effect a more complete settling of the fine sands, because the water will remain longer in each separator and the present vehement stream will be comparatively eased, and less material will be thrown upon the crowded rotating-tables, on which the losses are still large. That the slant must vary with the quantity of rock treated or water used, I need hardly say. Finer sieves on the jiggers will easily stop any running off of the fine copper, which fine copper is so characteristic of the Allouez rock.

Before concluding I wish to take occasion to express my thanks to Professor Egleston, whom I accompanied to Lake Superior as his assistant, in which capacity I was enabled to obtain data and suggestions which it would otherwise have been difficult to obtain.

Professor T. Egleston said: The conglomerates of Lake Superior and the methods of dressing copper are subjects to which I have given a good deal of attention, having spent the greater part of last winter in investigation in New York, and some weeks of last summer on Keeweenaw Point for that purpose. Mr. Roelker, whose able paper we have listened to with so much interest, was my assistant during the summer, and was afterwards stationed at the Allouez mine.

The methods of mining and extracting copper at Lake Superior have not had the attention from engineers which they deserve, and consequently but little is known of them. The very shortsighted policy of the State of Michigan in stopping the recent survey after it had been so ably conducted up to a certain point, and in threatening oppressive legislation to the district, is a real impediment to the

progress of the successful development of the mineral wealth of that country.

The difficulty of determining the geological equivalents of the different beds is much greater in Lake Superior than it would seem, for there are not only changes in their direction and thickness, but each bed, with its surrounding rocks, is more or less pseudomorphosed and altered, so that at long distances the determination of the equivalents of the different beds is very difficult. Add to this, that the occurrence of the copper in the same beds is exceedingly variable, the uncertainties become multiplied to such an extent and so difficult of solution as to furnish a good reason why unassisted private capital should not attempt to solve them. An instance of this is found in the Osceola mine, which, though it is but a few hundred feet from the Calumet and Hecla, has one of its shafts in poor ground.

With all the work relating to the deposits of native copper in the different beds of that region, which has in reality only been commenced by the Geological Survey, we must confess that we really know very little about its mode of occurrence, and that the methods of treating the ore are very crude, though much superior to what they formerly were.

The amygdaloid rocks have been the most studied, as the older mines were exclusively in these rocks. The conglomerates were formerly pronounced by the best authorities barren rocks, of which nothing was to be expected, and it is only within a few years that the most successful copper mine in the world has been developed in them.

The conglomerates are themselves of special interest on account of the very great variety in their form and constitution. The Allouez conglomerate on the foot-wall is a very coarse puddingstone, whose elements are from 0.05 to 0.08 millimeters in size. At a distance of 0.60 centimeters it commences to grow finer, when it assumes the form of a quartzose porphyry, until at the centre of the bed it becomes what the miners call "a sandslip," which might easily be mistaken for a fine-grained sandstone. Towards the hanging wall its elements grow coarser again, though not attaining much over 0.5 millimeter in size, but remaining a quartzose porphyry. As a general thing, although there is no absolute division between the walls, the separation is quite easy, and the rock at this point is of quite uniform character. It varies, however, in the quantity of copper which it contains. The foot-wall is an amygdaloid generally free

from copper, but occasionally it rises into the conglomerate, in which case it bears copper, and is taken out with it. The conglomerate not only varies in different parts, but in its physical conditions, for, correctly speaking, the rock is of exactly the same nature, whether it appears as a puddingstone, a quartzose porphyry, or a fine sandstone. It also varies in different localities in the mine. There are places, for instance, where the sandslip is almost free from copper, at other places it is almost pure copper. To the eye the rock, whether rich or poor, has the same appearance. This sandslip varies from three to fifteen or sixteen inches in depth, and as the whole bed is not worked, forms a very convenient point of separation. The mine is worked from the foot-wall to the sandslip, at both of which points it generally separates with great ease. In working the conglomerates the shafts are sunk upon the bed itself, with the object of making them pay for a part of the expense. They are sunk about six hundred feet apart, with winzes in the interior of the mine for ventilation.

In many of these mines the sides of the shafts are not carefully preserved, and the result is that some of them have been compromised, and others ruined by want of this precaution. I made a measurement of the dip of the Allouez bed, and found it to average about 36°. In one instance the dip is as low as 15°, but this is over a very small space, and is an accident. I measured the thickness of the bed across the vein, and found it on the second level to be 42 feet. This would give about 27 feet of vertical thickness between the walls. At this point there was a drift from the foot to the hanging wall, and the latter had been explored for about 100 feet.

The system of mining is that of overhead stoping. The system of filling up the old works with waste rock from the burrows has been adopted in a few cases, the poor rock being allowed to slide into the mine and fill up a part of one of the upper levels without having much work done inside. This is a good system, especially where the sides of the shafts have been beaten away for the copper they contain, for when the hanging wall starts to move, no wood or anything else but a very heavy rock-wall can support it.

There are some curious accidents in a mine, which are called crossings. Two of these occur in the Allouez, which dip the one towards the other. They consist of narrow bands of red clay, which preserve the structure of the rock, and in which the different materials are distinctly visible, even to the shape and color of the feldspar crystals. In place it looks like the rock, but is a little darker.

It is so soft, however, that it can be easily crushed in the fingers. These bands of clay have disturbed the mine very much. Wherever they appear the rock is poor. There is a general theory that the copper in these mines runs in shoots. This, however, does not seem to me to be proved in any but the Calumet and Hecla mine, which shows two distinct shoots of copper with poor ground between them, both of them running north. It is quite common, however, to hear a general conclusion drawn from this fact, and the assertion made that because the Calumet and Hecla shoots run north, therefore there will be shoots in all other mines which also run north, a conclusion hardly justified by the premises, and not borne out by experience. The interior working of the mine is simple. The large pieces are blockholed in the mine, and dumped from a car in the shaft-house on to a grating, roughly sorted and picked, 25 to 30 men being required for the purpose of sorting and selecting 200 tons of rock a day, and it is then only approximately done. The shoots into which the ore is dumped at the mills are not always arranged at the proper angle, and there is frequently too much labor expended there, besides no attempt is made to sort the rock. After a superficial selection in the shaft-house it all goes into the Ball stamps, and although it is a well-known fact that it takes as long to get fine rock through the gratings of the mortar as it does to stamp coarse rock, no attempt is made to screen the ore going into the stamps. There is a defect in almost all the mills that they use too much water in their washers, and a great deal of copper is lost both as float copper and as small amounts of copper carted off in the rock.

Five of the assays that are mentioned I made after careful sampling. I frequently picked out from the beach stuff pieces carrying a very considerable percentage of copper which had been washed into the tailings.

The results of dressing are called *mineral*. This is sent to the smelting works wet, the water being charged as copper. It could be very easily dried with the waste steam, with an apparatus which would cost very little for installation and nothing for repairs. I made this suggestion to a number of the agents of the mines, but as no one else had done it, failed to convince them, though there is a superabundance of waste steam in all the mills. There is but one mine, the Franklin, that dries the ore, and it is done in a very imperfect and costly manner; the principal object of doing it there seemed to be that it afforded an occasion of looking over the copper in small quantities, so that the boys who do it have an opportunity

of picking out more of the silver which occurs with the copper. The apparatus used could hardly be said to be efficient as a drier. There is very little doubt but that the iron which is contained in such large quantities in No. 4 and 5 could be separated. No attempt, however, is made to do it, but it would certainly pay, as it is all weighed and treated as copper.

There is a serious defect in most of these mills from the fact that they bring the water long distances in launders. These frequently freeze in winter. During very high winds they commence to freeze at the bottom from the draught which circulates underneath them. In cold still weather they freeze wherever there is a change of current, owing to the settling of the supports. It would be better in most cases and cheaper to bring the water in ditches, as the launders need constant repair, sometimes burn down, and, as the thermometer goes down frequently far below zero, are constantly liable to freeze, when every man in the mine and mill must turn out and work night and day to cut out the ice. If the water was run in earthen banks and these were covered with branches, the snow would cover and protect the stream, and there would be no danger of a deficiency of supply. This is a very serious matter, for when the water is stopped the whole production of mineral is stopped, as the mill cannot work without water. I made the plan of the work of the tail-house which is presented in this paper, in order to ascertain exactly what the amount of work done upon the tailings was. There is great and unnecessary complication here, and in any case the tailings that are worth working should be classified, the coarse parts should be restamped, as they are at the Calumet and Hecla, and the fine should be treated by an entirely distinct method of dressing. It is exceedingly doubtful whether the Collom washers, which are used invariably on Lake Superior, though better than the machines tried many years ago, are the best machines for doing the work. Evans's rotary buddle is certainly a very great improvement over the ordinary buddle for dressing native copper, and it is probable that there are other machines which would be better if experiments could be made on their use.

The treatment of the tailings is exceedingly defective, and it seems to me could be made much more effective. 30 or 40 per cent. of the total yield of the ore, and sometimes more, is often lost in the tailings from improper treatment of the ore, while the tailings themselves, though they are handled many more times than they should be, do not yield much more than enough to pay the expenses

of the tail-house. This is owing to the fact that with the exception of the Calumet and Hecla the mines do not make assays. The only knowledge of what is being effected is gained from the shovel assay, made by the Cornish method of vanning on an ordinary long-handled shovel. Most of the dressing works are in charge either of Cornish men or of men who have no experience beyond Lake Superior, and who, consequently, with only local experience, are not the ones to make a change. Many of the mines are not rich enough to make any extended researches, so that each copies what the other has done.

One of the reasons for the want of success of some of the mines is too much readiness to spend a very large amount of money, not on the mine, where it properly belongs, but on surface improvements. It is not an uncommon thing to find mines which have a yield of one per cent. above their neighbors, running in debt, while the latter are either paying dividends or accumulating a surplus. The cause of this may frequently be found to be the money expended on the surface, when it should have been spent underground. It is sad to see a country so rich in mineral wealth as Lake Superior suffering from the bad reputation of mistakes made twenty years ago, and those of a few men at the present day, who have by sharp practice or ignorance given a bad name to this very rich mining country.

THE MANUFACTURE OF FERRO-MANGANESE IN BLAST FURNACES.

BY WILLARD P. WARD, CARTERSVILLE, GEORGIA.

HAVING been engaged during the past year in the manufacture of ferro-manganese in a blast furnace, I have imagined that some further information on this subject might be of interest to that large number of members of the Institute who are engaged in the iron and steel industries.

The great question of the economical production of good steel, ingot metal, or homogeneous iron (we scarcely know now what to call it) from good materials, and at reasonable prices, has, thanks to the intelligence and energy of a few American engineers, been successfully solved in this country. Nearly all first-class railroads, and many that would not rank so high, have adopted the Bessemer rail. Martin boiler-plates are rapidly gaining ground, in competition with

the best charcoal bloom iron. To use a Hibernianism, the brightest side of the iron trade is the steel trade. What is now required is a process to utilize this immense number of old iron rails which are so rapidly being thrown out, and make from them, mainly, good steel rails. Water-cooling will probably furnish the means of reducing the excessive cost of repairs in the Siemens-Martin process, and cheap ferro-manganese will prove the key to the solution of the rest of the problem. On these points, which have been so ably treated in papers read at previous meetings of this body, I will not enlarge.

A year ago I furnished a short paper on the same subject as the present one. I believed myself to have been the first to solve the question of making ferro-manganese in a blast furnace; but it appears from a paper by Prof. Blake that something of the same kind had been done in Austria several years before. The tone of his paper is such as to lead the superficial reader to imagine that the Austrian experiment was a metallurgical success; but if it be so regarded in Austria, the term has a very different meaning there from here. At all events, an American metallurgist had worked out the problem unaided, and I think with somewhat better success, as will appear upon comparison of the data of the two processes.

The furnace in which my work was done was 34 x 7½ feet, with one three-inch tuyere; the fuel, charcoal, and the blast (furnished by an overshot-wheel driving wooden tubs), insufficient at all times, and very unreliable and weak in the summer-time.

The first experiments were made to produce spiegeleisen. Much difficulty was experienced at first in getting an iron ore sufficiently free from phosphorus. A large bank of brown hematite was, however, found, which contained not over 0.005 phosphorus and over 50 per cent. of iron. The manganese ore employed was a manganite, or a mixture of manganite and pyrolusite, containing about 35 per cent. of metallic manganese and 12 to 15 per cent. of iron, the remainder, except some combined water and oxygen, being silica.

After a few months' work on 8 to 10 per cent. spiegel, I determined to endeavor to raise the percentage of manganese in the product; to accomplish which the proportion of manganese ore in the charge was increased, the burden lightened and more limestone used. The results obtained were satisfactory; and by following this plan, the ferro-manganese was brought up to 67.2 per cent. The necessary conditions for the production of these high alloys, in order to prevent undue loss of manganese in the cinder, are, that the tempera-

ture be high enough to reduce and melt the charge, and that the fusing-point of the cinder be nearly the same as that of the alloy produced. The plan reported by Prof. Blake as used in Austria, of adding very large quantities of limestone, would not at all answer our requirements.

He says that the following charges are used, the percentage of manganese in the product being in each instance affixed:

15 limestone 85 manganese ore	gives 25 per cent. Mn.
28.6 limestone 71.4 manganese ore	gives 29 per cent. Mn.
42 limestone 57 manganese ore	gives 35 per cent. Mn.

It is an interesting question, how much limestone would be required, at this rate, to make a product containing 67 per cent. of manganese!

The alumina in so highly basic a charge as the last given would doubtless act as a base; in which case the cinder would already be a sub-silicate, far below a singulo-silicate, the ratio of the oxygen of bases to the oxygen of the silicic acid being as 15 to 10. Now if more lime were added, as Prof. Blake suggests, would we not soon get to a good material for Siemens furnace-roofs instead of a good blast-furnace cinder?

Reckoning from the analyses given, the composition of the cinder from the charge of 42 limestone to 57 manganese ore would be about

Silica, ...	23.1	Protoxide of iron, .	11.6
Lime, ...	33.5	Alumina, . . .	6.1
Protoxide of manganese, .	25.7		——100.00

The large percentages of the metallic oxides (iron and manganese) would render this cinder more fusible than it otherwise would be, but it seems extremely doubtful to me whether it would melt at all in a small charcoal furnace.

Let us now examine the economical use of the manganese in the ore. The Reschitza works use, it is said, 1400 kilograms of ore to produce 50 kilograms of 35 per cent. ferro-manganese.

1400 kilos. Manganese ore contain 37.2 per cent. Mn_2O_3=25.89 per cent. Mn.	
	or 362.0 kilos. Mn.
50 kilos. ferro-manganese, 35 per cent., contain	17 5 " "
Lost, ...	344.5 kilos. Mn.

That is, 4.5 per cent. of the manganese contained in the ore appears in the metal, and 95.5 per cent. is lost in the cinder! This can scarcely be called a metallurgical success in any country. At my furnace, according to the average of three months' work, 270 lbs. manganese ore, containing 35 per cent. Mn., yielded 100 lbs. ferro-manganese, containing 55 per cent. Mn.

270 lbs. Manganese ore containing	35 per cent.	Mn	= 94.5 lbs. Mn.
100 lbs. ferro-manganese "	55 "	"	= 55.0 " "
		Lost in the cinder,	39.5 lbs. Mn.

That is, 58.1 per cent. of the total manganese in the ore appears in the ferro-manganese, or *more than twelve times as much as was utilized by the Austrian method.*

Of late at the Diamond Furnace there has been about ¼ of coke used with the charcoal, and now a Weimer blowing engine is to be put up of sufficient size to furnish ample blast, and up to 4 lbs. to the square inch pressure. With these improvements it is believed that better results can be obtained than those above cited.

One more point to which I would call attention is that even a smaller percentage of manganese appears in the cinder in making rich alloys than in making poor ones. The analyses of the product of this furnace have already been given in my former paper.* The same characteristics are still maintained; the carbon seldom if ever reaching three per cent.

There is one other point in the data given of the Austrian process to which I wish to direct attention, viz., the fact that so much iron is carried off in the cinder. Our slags scarcely show a trace of iron; what little there is probably coming from small included particles of ferro-manganese. I have seen, when the cinder was stiff and flowing badly from the furnace, large pieces of metal carried off in the cinder, and I think it more than probable that this was the case at Reschitza, as the cinder could certainly not have been an easy one to work.

The hearth of the Diamond Furnace is built of natural sandstone found on the furnace property. The boshes are also built of the same material. The lining of the furnace above the bosh is of brick made from a very silicious clay which occurs near the furnace. One lining has lasted over two years on ferro-manganese and spiegeleisen; and hearths last on an average about four to five months. I believe this sandstone is the best refractory material I have ever seen for the

* Vol. iv. p. 362.

purpose. It is very nearly pure silica. Rock lying near the surface in the quarry is usually pretty hard, but deeper in the ground it becomes softer, until a material having little more consistency than sand is reached. Dr. Little, the State Geologist of Georgia, informs me that he has observed this deposit of sandstone, and traced it for a long distance; at some points it is a hard rock and even a quartzite, at other places very soft and passing over into an itacolumite. The material we use and prefer is that of medium hardness, as being less apt to shale off in heating up the furnace, and easier to work than either the very soft or the hardest variety. One great difficulty we experienced was to find material to stand in the "half-charge," say for the four or five feet below the tunnel-head plate. We have tried brick, the same that stand well in the lower part of the lining. They soon become disintegrated by the action of the carbonic oxide. We have tried the sandstone, which stands so well in the hearth; but it soon gives out, owing, I think, to the cooling off of this portion of the stack when fresh charges are put on. We now use cast-iron segments. These plates are ten inches wide on one side, and four inches the rest of the way, filled up on the outside with brick and clay.

This "half-charge" has stood well. Some of the segments have melted a little on the face, but if all the cast flange were to burn out we would still have a wall of alternate plates of cast iron and brick between.

The clay which we use contains very coarse grains of sharp sand, naturally intermixed, without which the clay would be very elastic. Brick made from this clay burn red, yet are sufficiently refractory to stand for over a year in the arch of the combustion-chamber of the hot-blast.

THE SPECIFIC GRAVITY OF CERTAIN LEADS.

BY PROF. CHARLES P. WILLIAMS, PH.D., ROLLA, MISSOURI.

THE determinations of the specific gravities of a number of samples of lead produced in Missouri, which form the subject of this note, were undertaken with the view of ascertaining if any approximation to the purity of such leads could be reached in this manner. The results would seem to indicate that, whatever value the method may have in the case of the crude and more impure

leads, for any of the refined or the soft leads which would meet the requirements of the manufacturer of white lead the indications would be certainly fallacious and unreliable if not entirely worthless.

In a problem of the kind indicated, there are many disturbing factors. Not the least important of these is the admitted lessening of the density of the metal by hammering or rolling (Morveau*), probably on account of slight cracks resulting from such treatment,† a fact which, at the very outset of the work, introduces an element of uncertainty into the sampling of the metal. A second cause of error is found in the fact that, while in general the smaller the amount of impurities the higher the specific gravity of the lead, there are exceptions, "probably in consequence of differences in crystalline conditions."‡ According to Schweitzer,§ "lead in its purest state shows indications of crystallization, readily observable on the surface, which has the appearance of fern leaves or frost; minute quantities of impurities, to my knowledge copper and antimony, prevent the appearance of these figures and render the metal denser, and have probably been the cause of the high specific gravities given by Berzelius‖ and others."

In the third place, the method of operation has a marked influence. Streng¶ describes the change of specific gravity according as a platinum wire or a hair is used for suspending the lead; the first giving in one case 11.378, and the second 11.394; and, for a second case, 11.372 and 11.390, respectively. My own experience has been that the method with the flask invariably gave lower results than that with the hydrostatic balance, suspending the sample by a fine hair. As the specimens used in the flask determinations had been cut by the chisel into many smaller pieces, these results may be due to greater changes in the structure of the leads. It was found, also, that samples which had been reduced by the rasp gave still lower results than those cut by the chisel, both being determined in the flask.

With such liability to variations, arising from mechanical causes, from chemical composition, and from manipulation, as well as from

* Gmelin's Handbook, vol. v, p. 106.

† Kerl, vol. i, p. 694.

‡ Ib., vol i, p. 693.

§ On the Specific Gravity of Pure Lead, read at Buffalo meeting of American Association, American Chemist, November, 1876, p. 174.

‖ Specific gravity of lead "when in the utmost attainable state of purity," 11.445, according to Berzelius (Gmelin's Handbook, vol. v, p. 106).

¶ Kerl's Handbuch, vol. i, p 694.

other sources, the wide range of specific gravities given for "pure" lead is explained. Among the more recent determinations, I find the following:

Specific gravity of "extraordinarily pure lead" (prepared by Dick, determined by Tookey), chiselled out from the pig, 11.382 at 15.5° C. (Percy's *Metallurgy of Lead*, p. 3), reduced to 4° C. = 11.383. Matthiessen (*Jahresbericht*, 1860), 11.376 at 14° C. = 11.378 at 4° C. Reich (*Berg-und Hütten. Zeit.*, 1860, p. 112), 11.370 at 4° C.

Schweitzer (*loc. cit.*) lead, carefully prepared from sulphate, gave by three determinations, each reduced to 4° C., 11.345, 11.358, and 11.356, respectively, or a mean of 11.353.

For the annexed results the specimens were chiselled from parts of the ordinary pigs, and the determinations made with the specific gravity flask, using amounts of about twenty grams, and with all precautions to insure accuracy. The percentages of lead given were obtained by difference after estimating the foreign matters in one hundred grams. The specific gravities at the observed temperatures were reduced to 4° C. by the following formula:

$$G' = \frac{G \times g^{w}}{1 + .000089\ (4^\circ - t^\circ)},$$

In which G' is the required specific gravity at 4°; G, the observed specific gravity at t°; g^{w}, the specific gravity of water at t°, referred to water at 4°, as given in Kopp's table; .000089, the cubical expansion of lead for one degree, also according to Kopp. The specimens represent as many different brands; the numbers refer simply to the laboratory record:

No.	Per cent. Pb.	Sp. Gr.	Sp. Gr. at 4° C.	No.	Per cent. Pb	Sp. Gr.	Sp. Gr. at 4° C.
I . .	99 99247	11 359 at 21° C.	= 11 354	X. . .	99 96996	11.372 at 18° C.	= 11.371
II. . .	99 97469	11 340 at 18° C.	= 11.339	XI. . .	99 97191	11 351 at 17° C.	= 11.351
III. . .	99.98320	11.341 at 18° C.	= 11.340	XII. . .	99 97509	11 373 at 17° C	= 11 373
IV. . .	99 96359	11.347 at 12° C.	= 11.350	XIII. . .	99.91919	11.314 at 11° C.	= 11 318
V. . .	99.97774	11.368 at 17° C.	= 11 368	XIV. . .	99 94548	11.337 at 11° C.	= 11.344
VI. . .	99 97786	11 342 at 18° C.	= 11 341	XVI. . .	99.89337	11.329 at 18° C.	= 11.328
VII. . .	99.98078	11 356 at 18° C.	= 11.353	XVII. . .	99.74526	11.344 at 10° C.	= 11 346
IX. . .	96.92124	11.356 at 12° C.	= 11 359				

The mean of the above fifteen samples is 11.349 at 4° C., and the mean percentage of lead is 99.94138.

As a check on these results, equal weights of the leads were melted together in a graphite-coated Hessian crucible under potassium cyanide; the cast button, weighing about 200 grams, was carefully cleaned, and two determinations made of the specific gravity

at 15.5° C., using about twenty grams chiselled from the button for each trial.

1st trial gave specific gravity, ...	11.341 at 15 5° C.
2d trial gave specific gravity, ...	11.347 at 15.5° C.
Mean, ...	11.344 at 15 5° C.

Or, 11.346 at 4° C.

The mean percentages of foreign matters in the fifteen samples may be taken as follows:

As, . . .	0 00562 per cent.	Fe, . . .	0 00511 per cent.
Sb, . . .	0 01359 "	Zn, . . .	0 00231 "
Ag, . . .	0 00252 "	Ni, . . .	0 00191 "
Cu, . . .	0.02756 "		
			0 05862

Allowing nothing for contraction, the calculated specific gravity of a mixture of the above metals, in the proportions given, would be 7.6934, referred to water at its maximum density. Employing this factor and the mean of the observed specific gravities of the samples, and ignoring the contraction, which would be of small value, the calculated specific gravity of the theoretically pure lead would be 11.352, a result not differing materially from Schweitzer's mean of actual determinations.

A glance at the table will show that this value will not give even rough approximations to the percentages of metallic lead, and, for leads of the character used in the experiments, the method of specific gravity appears to be valueless as a test of purity.

HEAT REQUIREMENT AND GAS ANALYSIS AT CEDAR POINT FURNACE, PORT HENRY, N. Y.

BY T. F. WITHERBEE, PORT HENRY, N. Y.

THE following calculation of heat requirement covers the working of the furnace from January 25th to February 14th, inclusive. A short time previous to the first date the furnace had been working rather badly, so that 300 lbs. of ore and 500 lbs. of limestone were taken off. Within the time mentioned the quality of the iron passed

through all grades from white to No. 1, and finally changed to glazy white iron, until increased ore charges had their effect.

The analysis of materials used were made from samples weighing several tons, crushed fine, mixed and "halved down" in the usual manner. The ratio of the gases was found from an average of over 70 analyses with the Orsat apparatus. Blast temperature was taken with the Siemens copper ball pyrometer every two hours. The temperature of escaping gases was taken with a Gauntlet pyrometer, checked by a mercurial thermometer.

The following table gives materials used per pound of pig:

Materials.	Components.		Iron	Slag.	Gas.
Anthracite Coal. 1.393	Carbon, ...	1 154			1.119
	Nitrogen and oxygen, .	.018			.018
	Ash, ...	.180	.035	.180	
	Volatile matter, . . .	.041			.041
		1.393			
Magnetic Ore. 1.89	Fe_3O_4, ...	1.274	.923		.351
	SiO_2, Al_2O_3, CaO	.616	.040	.530	.046
		1 89			
Magnesian Stone. 7.14	Water, ...	.001			.001
	CO_2, ...	·.314			.314
	MgO, ...	.093		.399	
	CaO, ...	.208			
	SiO_2, ...	.038			
		.714			
			998	1.109	1.890

The heat requirement and production were calculated from the following data, according to the formulas of Bell and Gruner:

Total carbon, ...	1.154	Carbon in CO_2 of flux, .	.0853
Less carbon in pig, ...	.035	$\frac{CO_2 = .825}{CO = 2.285} = 361$, . .	$= m.$
Leaving for combustion, . .	1.119	C in CO_2	.225
		C in CO, ...	.979
		Total C in gas, . .	1.024 $= p.$

Oxygen of the blast, ...	1.281
" " ores and fluxes in gas, ...	.624
Total oxygen in gas, ...	1.905

WEIGHT AND COMPOSITION OF BLAST AND GASES PER UNIT OF IRON.

Blast.			Gases.	
Oxygen,	1.281		Carbonic Acid,	.825
Nitrogen,	4.166		Carbonic Oxide,	2.285
Moisture, .0062,	.034 (calculated)		Nitrogen,	4.166
	5.481		Moisture,	.018
				7.295

HEAT PRODUCTION.

C to CO,	.979 x 2473 =	2421
C to CO_2,	.140 x 8080 =	1129
Total from 1.119 C	=	3550 = 3171 per unit = 39.2 per cent.

HEAT DISTRIBUTION.

At tuyeres C to CO,	.9957 (89 p. c.) x 2473 =	2462
In zone of reduction C to CO,	.1233 (11 p. c) x 2473 = 305	1088
" " C in CO to CO_2,	.1397 x 5607 = 783	
		3550
Carried in by blast,	5.481 x .239 x 704° C. (1299° F.),	922
Total calories,		4472

HEAT REQUIREMENT.

For reduction			
Of iron,	.923 x 1887 =	1741	2064
" Silicon,	.04 x 8000 =	320	
" Phosphorus,	.0004 x 5747	3	
" Sulphur,	.0003 x 2560		
For fusion			
Of iron,	.998 x 330	330	962
" cinder,	1.109 x 570 =	632	
For decomposition			
Of limestone,	.715 x 373 =	267	649
" water in blast,	.034 x 3400 =	115	
" CO_2 of flux,	.0853 x 3134 =	267	
For evaporation of water in materials,	.019 x 606 =		12
For carried off by gases,	7.295 x .237 x 137° C. (791° F.) =		237
For carbon impregnation,	.035 x 2400 =		84
For radiation from walls, carried off by tuyere water, expansion of blast, etc., by difference,			464
Total calories,			4472

Heat produced as estimation by Mr. Bell would be:

C to CO, . . .	1 119—.0853 = 1.0337	x 2473 =	2556
C in CO to CO_2	.225	x 5607 =	1261
			3817

which exceeds the amount by Gruner's method 267 calories, or 7 per cent. From the known condition of the furnace it is evident that the calculation of Mr. Bell is nearest right.

Of the .1233 of C burned in zone of reduction .0853 would be burned by the CO_2 of the flux, and .038 by CO_2 from reduction of the ore, *i. e.*, 69 per cent. in the first place and 31 in the latter. The first gas analysis was made at Cedar Point about five months ago, at which time a much heavier burden was carried than now, the ratio of CO_2 to CO averaged considerably above .40, many times above .50, and even up to .68. The experiments were not, however, sufficiently numerous to entitle the higher numbers to much confidence, although it is difficult to see how an error could have been made.

A word in regard to the working of the Orsat apparatus. No difficulty is found in absorbing the CO_2, three passes being sufficient, but with the CO trouble begins. When the solution is first prepared, absorption is about *nil*, and only improves as the copper dissolves. At first it required over a hundred passes to entirely take up the CO. After using a fresh solution a few days, a record was kept of the cubic centimeters absorbed by each five passes until final absorption, which is given in the following table. It will be seen that the first five passes take up nearly or quite $\frac{2}{3}$, but the remainder resists absorption.

The table, if extended further, would show that after improving until 15 immersions sufficed the absorptive power began to fail.

The CO cylinder has been modified in several ways to see if its operation could not be improved. First the bell-glass was filled with glass tubes, each having a piece of copper wire inside. That was a complete failure, probably owing to the tubes having accidentally become coated with grease and wax, so that the liquid was repelled, and the surface of contact diminished instead of increased as intended. Then the bell-glass was lined with fine copper gauze, and several disks of the same material put in the upper end to strain the gas through, under the disks a thin layer of glass marbles came next, and then alternate layers of disks and marbles until it was full. Absorption was completed by this plan in five passes, but it required careful handling to prevent trapping in the gas, and it was abandoned.

TABLE SHOWING C.C. OF CO ABSORBED FOR EACH FIVE PASSES, ETC.

Analysis No.	1	2	3	4	5	6	7	8	9	10	11	Total No. of passes	CO_2	*m*
13	9 5	5	4	3.	2.5	1 5	1 5	1.	.5	0	.5	55	7	.379
14	11	7	5	2.5	1.5	1.	1					35	7	379
15	12	7	4	4	1	5	0	5				40	7	.386
16	9	6 5	4 5	2	2	1 5	1	1	5			45	8	.449
17	10 5	6 5	2	3	2	1.	1	5				40	6.5	.353
19	11	6 5	4 5	3	1 5	1	.5	5	.5	0	.5	65	7	379
20	14 5	7	4	2 5	1	1						30	6 5	.341
21	13	7 5	4 5	2 5	1	1.	.5					35	6 5	341
23	15	7 5	4	2	.5	.5	5					35	6 5	.346
24	15	6 5	3 5	2	1	.5	.5					35	7	.379
26	15	7.5	4	1 5	1	.5						30	7	373
27	14 5	7 5	3 5	1.5	1	5						30	6.5	.359
28	16	7.5	3 5	2	5	.5						30	7	.367
29	17 5	7	3	1.5	5							25	7	.373
30	17	8.5	3	1	.5	.5						30	6 5	.355
31	17	7 5	3	1.5	.5	.5						30	6.5	341
32	16	7 5	3	1.5	.5							25	7	373
34	19 5	7	2.5	1	.5	.5						30	6 5	.335
35	19 5	7	3	1								20	6 5	.335
37	18.5	7	3	1								20	6.5	.346
38	19	5 5	2	.5	5							25	6	.337
39	20	7	2 5	1		.5						30	6	.304
40	19 5	7	3	.5	.5	.5						30	6	335
41	24 5	5 5	1.5									15	6 5	.324
42	23 5	5 5	1.5									15	7	.355
43	22 5	6	1.5	.5								20	6.5	.335
44	21 5	6	1 5	5								20	7	.373
45	22	6	2	.5	.5							25	6.5	.335
46	23 5	5 5	1	.5								20	7	.373
47	21 5	6 5	1 5	.5								20	7	.367
49	24 5	5	1.	.5								20	7	.352
50	24 5	5	1 5									15	7	.361
51	23 5	5	1.5									15	7	.361
52	22.5	6	1 5	.5								20	6.5	.341
53	22 5	6	1 5	.5								20	7	.361
54	22	7	1 5	.5								20	7	.352
55	23	6	1	.5								20	7	.361
56	23	5.5	1 5									15	7	.367
57	22	6 5	1 5	0	5							25	7	.361
58	21	6 5	1 5	.5								20	6 5	.346
59	20 5	6 5	1.5	.5								20	7	.379
60	24 5	5	1	.5								20	6.5	.335
61	24 5	4.5	1	.5								20	6.5	.341
62	19 5	6 5	2	1								20	6.5	.353
63	19	6	2 5	.5	.5							25	6.5	.359
64	19 5	6 5	2.5	1								20	6.5	.319
65	19 5	6.5	2	1	.5							25	6.5	316
66	24	5	1									15	8	.419
67	24	4 5	1	.5								20	8	.433
68	25 5	5	5									15	6 5	.362
69	24	4	1									15	5.5	279
70	21.5	6	2	1								20	6	.314
71	21	6	1	1								20	6	.319
Average, including analyses not in table														.361

MEMORANDUM —The total number of c.c. given in each analysis will not in every case show the correct amount of CO to give the proper value of *m*, which is owing to the position of the aspirator at each particular time, the numbers given for rate of absorption being *relative* and not comparable with CO_2 in every case.

The best results were obtained by filling with marbles about 5 mm. diameter inside the gauze lining, ten to fifteen passes being sufficient, and no danger of mechanical loss of gas. The above experi-

ments were made with the same liquid that had begun to fail with the old way of mounting, *i. e.*, simply a roll of copper gauze inside the bell-glass.

Since the heat requirement here given was calculated the ore charges have been increased, which is shown by the gas analysis, m, being now .388, while .40 indicates good work at this furnace.

The ratio of the gases, taken in connection with the heat requirement, is found to be a good indication of the working of the furnace, but taken alone the equation $\frac{CO_2}{CO} = m$ must not be considered a metallurgical returning board. Now that gas analyses are so easily made, it is hoped that the working of anthracite furnaces may be fully shown up, and thus allow results to be compared after "all disturbing causes are eliminated," which Mr. Bell shows to be necessary.

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